University of Southern Queensland

Faculty of Health, Engineering and Science

Methods of Feeding out White Cottonseed to Livestock

A dissertation submitted by

Damien Christopher Wooldridge

In fulfilment of the requirements of

Courses ENG 4111 and 4112 Research Project

Towards a degree of

Bachelor of Engineering (Mechanical)

Submitted: October 2014

Abstract

With the ever increasing demand of beef export from Australia, the importance of maintaining livestock health is becoming increasingly difficult with the current climate changes. Producers are forced to source new feed at lower cost to them but keeping the same nutritional value for their livestock. One of these 'super nutrient' feeds include White Cottonseed (WCS). WCS is the waste product of the cotton ginning process and is given the nickname of 'triple nutrient'. High in fat, protein and fibre of this product keeps the livestock fed for longer periods and is cheaper to source since it is a waste product. The main difficulty producers have with the supplement is the physical handling of it. It proves difficult to flow and binds together in a Velcro like nature. The need for a system that can overcome this difficulty will make the feeding of this product simpler and less demanding on the producer.

This project aims to research into the current methods of feeding this product, looking into the current systems being used for this application and creating an improved or new system to be implemented. Since this project is aimed at drought effected producers, low cost is the biggest priority. Through an extensive literature review it was found that there is basically no system available worldwide that meets the demand of this project hence the creation of a new prototype is to be implemented. The limits created for this prototype were low cost, must fit in the confines of a utility tray, powered solely by the 12 Volt DC supply from the utility and should contain a modified floor system that will move the feed from a storage bin to a portion dispenser unit.

After a critical analysis of the current methods it was discovered through a decision matrix, that a modified conveyor system would be most appropriate for this specific application. The conveyor is to have teeth on the belt that will pull at the product and deliver it to a trap door dispenser unit that will drop a portion every six to eight meters significant enough to feed six head of cattle. The timing will be operated by a gear and chain drive off the main axle. The whole system will be driven by a 12 Volt DC Electric Motor and the initial prototype size will hold approximately 750 kg of WCS. The whole design will come within the given budget at an estimated cost of $5400.00 AUD. This is relatively cheap in the feeder market and should prove to be easily marketable to producers in Australia. The added benefit of such a system include the huge reduction in time required to feed livestock. Also the physical demand will be greatly reduced as the system will be fully

automated and push button activated. The system will also be able to be utilised while the producer is checking his cattle or other jobs throughout his property. Finally the system will not be limited to WCS but will be able to be used for many other feed products including grain, feed pellets etc. The prototype designed by this project will benefit producers throughout the agricultural field greatly and proves to have significant potential.

University of Southern Queensland

Faculty of Health, Engineering and Sciences

ENG4111/ENG4112 Research Project

Limitations of Use

University of Southern Queensland

Faculty of Health, Engineering and Sciences

ENG4111/ENG4112 Research Project

Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Damien Wooldridge

0050100276

Acknowledgements

This research project was undertaken under the guidance and supervision of Dr. Guangnan Chen (University of Southern Queensland) and the question prompted by an Australian farmer Pamela O'Neill.

I would like to thank and congratulate these people for their continued commitment, effort and helpfulness throughout the duration of this project. A special thank you goes to Dr. Guangnan Chen for his high standard of supervision and extremely punctual service during the process of the project.

I would also like to thank my family and friends for standing beside me and helping me achieve my ambitions and a goal within my life. Many thanks again to all people associated with the University of Southern Queensland and engineering life

DAMIEN WOOLDRIDGE

Mechanical Engineering Student

October 2014

University of Southern Queensland

Toowoomba, Australia

Table of Contents

Abstract 2

Limitations of Use 4

Certification of Dissertation 5

Acknowledgements 6

Table of Contents 7

List of Figures 10

List of Tables 12

List of Appendices 13

Nomenclature and Acronyms 14

1 Introduction 15

1.1 Project Background 15

1.2 Project Aims 17

1.3 Overall Project Methodology 17

1.4 Design Methodology 18

1.5 Outline of the Thesis 20

2 Background and Previous Research 21

2.1 Drought Effected Livestock 21

2.2 Feeding Livestock White Cottonseed 23

2.2.1 Nutritional benefits and cautions to Livestock 25

2.2.2 Cost effectiveness to producers 27

2.2.3 Sustainability and availability of WCS supply 30

2.3 Applicable Scenarios for Design Limitations 31

2.4 Previous Research of Automated WCS Feeder 33

2.5 Conclusion 39

3 Methods of Feeding Livestock White Cottonseed 40

3.1 Manual Feeding Process 40

3.2 Agricultural Machinery Feeding Process 41

3.3 Troughs and Feeders 42

3.4 Mill Processing 44

3.5 Automated Feeding Process 45

3.5.1 Screw Conveyor 46

3.5.2 Conveyer Belts 48

3.5.3 Chain Bed 50

3.5.4 Automated Bucketing System 51
3.5.5 Gravity Fed 53
3.5.6 Pneumatic and Hydraulic System 54
3.6 Conclusion 56
4 Critical Analysis of Existing Systems 58
4.1 Initial Design Criteria 59
4.2 Requirements of Final Design 61
4.3 Comparing Existing Systems to Requirements of Final Design 62
4.3.1 High structural durability and heavy duty components 63
4.3.2 Maximum and minimum size limits 64
4.3.3 Perform from 12 Volts 66
4.3.4 Low Cost 66
4.3.5 Can adequately handle WCS in its raw form 68
4.4 Selection of Usable System 72
4.5 Final Critical Comments 72
5 Preliminary Design Considerations 74
5.1 Summary of Existing Systems and reasons why they are currently not being used 74
5.2 Design Conditions 79
5.3 Key Overall Design Parameters 79
5.3.1 Overall Machine Size 80
5.3.2 Power Sources 81
5.3.3 Desired Feeding Rate 82
5.3.4 Maintenance 83
5.3.5 Cost/Budget 83
5.4 Conclusion 84
6 Generation of Conceptual Design 86
6.1 Conceptual Design Limitations 86
6.1.1 Materials 86
6.1.2 Manufacturing 88
6.1.3 Operator Instructions 88
6.1.4 Mounting Device Methods 89
6.2 Conceptual Design Sketches and Explanation 90
6.3 Modelling Software Decision 91

6.3.1 Current Software Available ... 91
6.3.2 Chosen Software Explanation ... 92
6.3.3 Conclusion ... 92
6.4 Modelling Software Concept Generation ... 92
6.4.1 Initial Plan for Model Generation ... 93
6.5 Final Conceptual Drawings ... 94
6.5.1 Sketches and Detail Plans ... 94
6.6 Conclusion ... 96
7 Prototype Specifications ... 97
7.1 Final Prototype Drawings and Calculations ... 97
7.1.1 Prototype Calculations ... 97
7.1.2 3D Prototype Creation ... 98
7.2 Estimated Component Costs ... 99
7.3 Implementation into Farming Practice ... 101
7.4 Plan for Construction and Testing ... 102
7.5 Conclusion ... 103
8 Conclusion ... 104
8.1 Conclusion ... 104
8.2 Recommendations for Future Work ... 105
References ... 107
Appendices ... 111

List of Figures

Figure 1 - Beef Cattle Production (Source: (PWC 2011)) 15
Figure 2 - White Cotton Seed (Source: http://www.tirupatifiber.com/full-images/cotton-seed-1012172.jpg) 16
Figure 2.1 - Rainfall Deficiency (Source: http://www.bom.gov.au/climate/drought/) 21
Figure 2.2 - Queensland Drought Situation (Source: http://www.abc.net.au/news/2014-03-07/march-drought-map/5306506) 22
Figure 2.3 - Nutrient Composition of Cottonseed (Source: (Blasi & Drouillard 2002)) 26
Figure 2.4 - Hay Bale Feeder (Source: http://www.haysaverfeeder.com/images/hayConserverBaleFeeder-Quotes.jpg) 29
Figure 2.5 - Trip Hopper Feeder Small Truck Model (Source: http://www.tsfeeders.com/graphics/jr_01.jpg) 34
Figure 2.6 - Trip Hopper Feeder Large Truck Model (Source: http://www.tsfeeders.com/graphics/pu_01.jpg) 35
Figure 2.7 - Trip Hopper Feeder Trailer Model (Source: http://www.tsfeeders.com/graphics/tr_01.jpg) 35
Figure 2.8 - Bar6 Feed Dispenser (Source: http://bar6.net/feed-dispensers/) 36
Figure 2.9 - V Mix Plus (Source: (Lengerich 2014)) 37
Figure 2.10 - Heavy Duty Cube Feeder (Source: http://tarterusa.com/tarter-products/heavy-duty-cube-feeder/) 37
Figure 2.11 - Mobile Feed Out Bin (Source: http://www.commanderagquip.com.au/products/1ton-silo-mobile-feed-out-bin-with-tarp) 38
Figure 3.1 - Grain Shovel (Source: http://www.shtfplan.com/wp-content/uploads/2010/10/shovel.jpg) 41
Figure 3.2 - Front End Loader (Source: https://www.deere.co.uk/en_GB/media/images/our_company/news_and_media/press_releases/2013/nov/John_Deere_5100M_tractor_H260_front_loader.jpg) 41
Figure 3.3 - Open Air Feed Trough (Source: http://www.lumber2.com/v/vspfiles/photos/BW-25564F-2.jpg) 43
Figure 3.4 - Grain Feeder (Source: http://www.westbrookengineering.com.au/wp-content/uploads/2009/03/westbrook-0083-300x225.jpg) 43
Figure 3.5 - Stationary Hammer Mill (Source: http://cfnewsads.thomasnet.com/images/large/503/503663.jpg) 45
Figure 3.6 - Screw Conveyor (Source: http://img.tfd.com/ggse/e0/gsed_0001_0012_0_img2865.png) 47
Figure 3.7 - Conveyor Belt Assembly (Source:http://www.heenaindustries.com/wp-content/uploads/Belt-Conveyor.jpg) 48
Figure 3.8 - Chain Weave Conveyor (Source: http://www.meshbelt.com/files/chain462a12.jpg) 50
Figure 3.9 - Cotton Chain Bed (Source: http://www.deere.com/en_US/docs/agriculture/cotton_harvesting/cotton_modules/cotton_module_staging_instructions_truck_requirements.pdf) 51

Figure 3.10 - Bucket Wheel Excavator (Source: http://img.directindustry.com/images_di/photo-g/bucket-wheel-excavators-58589-4549569.jpg) 52
Figure 3.11 - Hydraulic Circuit (Source: http://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Hydraulic_circuit_directional_control.svg/301px-Hydraulic_circuit_directional_control.svg.png) 55
Figure 4.1 - Small Scale Conveyor Belt System (Source: (Corp. 2013)) 65
Figure 4.2 - Small Scale Screw Conveyor (Source: http://millardmfg.com/products/Pictures/135569390.jpg) 65
Figure 4.3 - Example Tooth Concept (Source: http://www.lane.us.com/images/woodfd-2.jpg) 69
Figure 4.4 - Conveyor Belt Modification Examples (Source: http://www.morinex.com/images/jpgs/4945lr.jpg) 69
Figure 4.5 - Conveyor Belt Teeth (Source: http://i00.i.aliimg.com/img/pb/709/248/519/519248709_067.JPG) 70
Figure 4.6 - Conveyor Insert Example (Source: http://www.martin-eng.com/products/media/catalog/product/cache/1/image/800x800/9df78eab33525d08d6e5fb8d27136e95/b/c/bc07003h.jpg) 70
LEFT Figure 4.7 - Tooth Bucket (Source: http://imavex.vo.llnwd.net/o18/clients/runyonrental/images/4100.jpg) 71
RIGHT Figure 4.8 - Straight Bucket (Source: http://www.attachmentscjj.com/images/dirt-bucket.jpg) 71
Figure 5.1 - V Mix Plus (Source: (Lengerich 2014)) 74
Figure 5.2 - Bar6 Feed Dispenser (Source: http://bar6.net/feed-dispensers/) 75
Figure 5.3 - Heavy Duty Cube Feeder (Source: http://tarterusa.com/tarter-products/heavy-duty-cube-feeder/) 76
Figure 5.4 - Trip Hopper Feeder Trailer Model (Source: http://www.tsfeeders.com/graphics/tr_01.jpg) 77
Figure 5.5 - Trip Hopper Feeder Small Truck Model (Source: http://www.tsfeeders.com/graphics/jr_01.jpg) 78
Figure 5.6 - Trip Hopper Feeder Large Truck Model (Source: http://www.tsfeeders.com/graphics/pu_01.jpg) 78
Figure 6.1 - Ring Lynch Pin (Source: http://www.hisltd.co.uk/images/APerryLynchPinRing.jpg) 90

List of Tables

Table 1 - Method Comparison 56
Table 2 - Design Decision Matrix.. 72
Table 3 - Design Consideration Conclusions 84
Table 4 - Materials List 100
Table 5 - Component Costing.. 100

List of Appendices

APPENDIX A - PROJECT SPECIFICATION

APPENDIX B - COTTONSEED FEED PRODUCTS FOR BEEF CATTLE

APPENDIX C - EASIFLO COTTONSEED BROCHURE

APPENDIX D - INITIAL CONCEPTUAL SKETCH (ISOMETRIC VIEW)

APPENDIX E - INITIAL ORIENTATION SKETCH (FRONT/REAR VIEW)

APPENDIX F - INITIAL ORIENTATION SKETCH (TOP VIEW)

APPENDIX G - TRAP DOOR DISPENSER UNIT INITIAL CONCEPT

APPENDIX H - ORRCON STEEL PRECISION SHEET BROCHURE

APPENDIX I - ORRCON STEEL STRUCTURAL SHS BROCHURE

APPENDIX J - PROTOTYPE SKELETON ISOMETRIC VIEW

APPENDIX K - FINAL PROTOTYPE ISOMETRIC VIEWS

APPENDIX L - PROTOTYPE DETAIL DRAWING

Nomenclature and Acronyms

WCS - White Cotton Seed

mm - Millimetre

kg - Kilogram

AUD - Australian Dollar

1 Introduction

1.1 Project Background

The Australian cattle industry is growing at an ever increasing rate, being the world's third largest exporter of beef that houses a gross value of approximately $7.4 Billion dollars. The benefit this industry has on the economy of Australia is enormous, not only producing approximately $12.3 Billion dollars worth of meat products but also generating 200,000 jobs across farm, processing and retail (Australia, M. A. L. 2014). Producers continue to expand further into the Australian outback where the climate becomes more hostile and poses its challenges to successfully meet the demand of the export market. The abundance of space makes the Australian outback an excellent position to run livestock properties for beef cattle. In fact over 60 percent of Australia's land is devoted purely to the use of agriculture. The beef cattle industry, in particular, accounts for 57 percent of all farms and agricultural activity in Australia (Australia, M. A. L. 2014) and will be the governing type of livestock discussed throughout this project. Shown in Figure 1 we can see where the majority of these beef cattle farms are located and the area that they occupy throughout Australia.

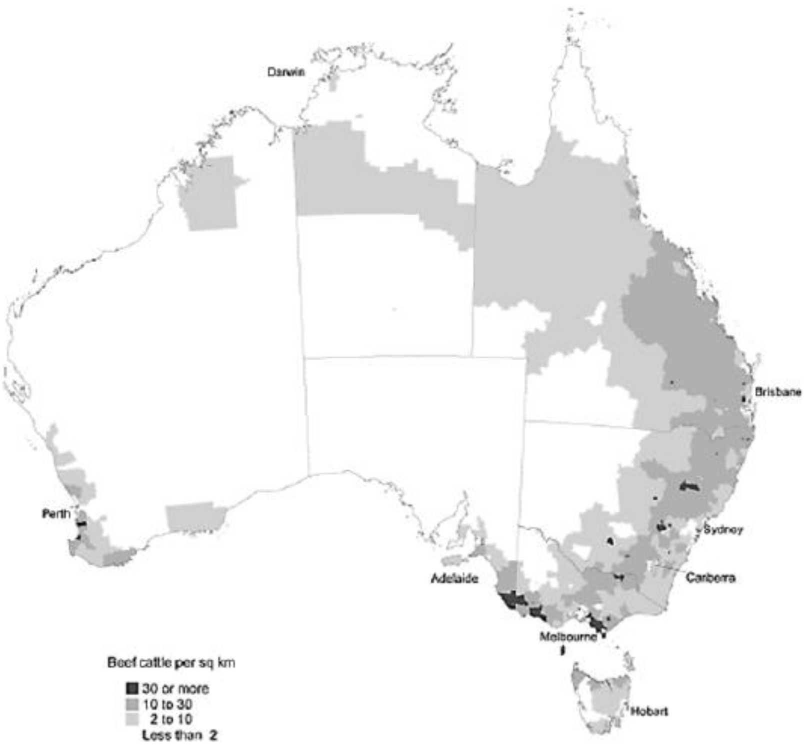


Figure 1 - Beef Cattle Production (Source: (PWC 2011))

Due to the ever changing climates, farmers are faced with a challenge of sustaining sufficient feed to continue the production of high end beef products for the Australian consumers. Drought affected areas are in particular need for alternate sources of feed during these tough seasons. When the natural source of feed is little to none, specific diets are implemented to effectively keep the livestock healthy. One particular source for this sustainability is the use of white cotton seed (WCS) which can be seen in Figure 2 below.

Figure 2 - White Cotton Seed (Source: http://www.tirupatifiber.com/full-images/cotton-seed-1012172.jpg)

WCS is the seed remaining after the ginning process of cotton. It is particularly dense in nutrients like protein and fibre. Rumination, better known as the digestion process, of WCS causes a slow release of nutrients which means the livestock remain fed for longer (Blackwood 2007). The nutritional and sustainability benefits of implementing this product will be discussed in more detail in Chapter 2 but as seen from the figure above the product has physical properties that causes handling to become a problem. Due to its physical makeup, there are only a limited number of ways to handle the product and feed it out to livestock. Potential ways include manual labour or the use of agricultural machinery. However the availability of automated machines for this process are hard to come by and expensive to purchase. These remarks prompt current research into the availability of existing devices and whether these current devices can adequately and successfully complete the task of feeding out WCS to livestock in an automated fashion. These sourced devices will be appropriately compared and analysed on how well they meet problem requirements and whether they can be implemented into a new design. The new design concept will be created either by optimising a current design or by means of inventing such a device. Throughout the project research decisions will be made on how to best meet all requirements of this cotton seed feeder.

1.2 Project Aims

The broad aim of this project is to develop an improved method for feeding out white cotton seed to livestock. Livestock producers use this by-product of cotton production as a drought supplement feed. The process of feeding the by-product to livestock can prove to be a problem due to the physical composition of cotton seed and its difficulty to handle. The means of feeding this product have been reduced to manual labour due to this disadvantage of the by-product. This project aims to implement a mechanical device that can be used by one operator and automates the process of distributing cotton seed to livestock. The aim of the device is to remove basically all manual labour and to optimize the process of feeding out cotton seed. This project also aims to adequately compare existing machinery currently used for this sole purpose and to create an optimised conceptual design from the findings. Cost is a crucial design factor due to the financial difficulties producers are exposed to during these times, meaning this project aims to create a relatively affordable device that can meet these criteria.

1.3 Overall Project Methodology

As outlined in the project specification the following objectives need to be met for the successful completion of this project.

1. Research existing information relating to machinery used for feeding out cottonseed to livestock in the world. This will include a literature review of alternative design principles and the need for such a device.

2. Identify and develop suitable design specifications.

3. Develop and cost an improved prototype using a commercial solid modelling program. Designs should incorporate purchasable items and manufacturable parts.

As time permits:

4. Construction of the prototype for testing.

The main specific objective of this research project is to identify and develop a suitable design for practical implementation of such a device. To be able to meet this objective successfully a literature review must first be undertaken to gather information on any existing devices used for this purpose. This literature review will include an extensive background on the reason why this device is needed. Due to my limited knowledge of feeding out of cotton seed, research in the current approaches to this problem needs to be revealed and compared. Consulting local rural suppliers, local livestock producers, books, texts and internet sources will be the commanding source of literature and comparable information used in this literature review. All these sources will make up the greater portion of the research.

The purpose of exposing the background on this particular problem will give grounds on how appropriate others have attempted to solve this problem at hand and give excellent guidance on what works currently and what options have room for optimisation. By using the information found, an optimum method of feeding out cotton seed will be discovered and practically implemented into a device. At this stage some conceptual design sketches will be completed to thoroughly explain the design ideas and to give a more appropriate perspective on the design. These sketches will include initial dimensions for scale and ease of implementation into 3D Modelling software.

Finally after the appropriate design has been discovered and implemented into a conceptual stage a computer model will be created using appropriate dimensions. This design will include costing and the introduction of real life manufactured parts for the possible creation of a prototype of the design. This final step will only be conducted if time permits after all research and development has been completed.

1.4 Design Methodology

This research project aims to create an automated White Cottonseed feeder that can be used by a producer single handed and with ease. Meeting this requirement while keeping costs at a minimum is very important. The plan for this project is to follow the project specification and keep close accordance with the various deadlines. There are a variety of things that need to be considered before design work is undertaken. These include resource analysis and risk assessment, as well as an appropriate timeline to follow during the progression of this project. But before this can be addressed a plan needs to be discussed.

The initial stage of the design process is the background research into the variety of design considerations that could be used in the final design concept and an extensive discussion on why such a device will benefit producers. Research into White Cottonseed as a product will be another big part of this initial research stage. This initial work needs to be completed by the 4th June 2014 as the preliminary information needs to be included in this document. A variety of design considerations needs to be included in this document as well which can then be used in the creation of the final concept. This is the first stage of the project construction and has a tight deadline hence all research and writing should be completed one week in advance for critiquing and collaboration.

The second stage that will be considered is the critical analysis of the existing systems as well as a variety of new systems that could be implemented into the concept design. This stage is extremely important and will take use of weighted charts with appropriate criteria to best choose a design to test in the prototype. These criteria will include cost, ease of use, ease of manufacturing and whether or not the device will meet the demands of the project. This stands to be the most important section following the research and will be expected to be completed by July 6th 2014 so that conceptual designs can begin to take place. Having this completed earlier will benefit the project as time will be freed for the building of the concept after design. However the major goals of this design project are to create a concept not a working model if time does not permit.

The third stage of the design is to identify and develop suitable design specifications so that the prototype can be created and costed. A variety of methods will be used here as my background in design is limited. Consulting standards for a variety of agricultural devices and research into the design of mechanical objects of this nature will be a significant part in decided on the specifications. Also consulting local producers and using specifications from any found existing devices will be utilised if possible for better analysis of the design. Specifications will be limited due to the scope of the project and costing will be a consideration highly valued. The importance of sourcing a variety of design standards and producers opinions will improve the validity of the concept and increase the chance of successfully creating a device to meet the problem. This section will be due September 1st 2014 to allow for implementation of the discovered specifications into the concept. This deadline is crucial for this section to allow plenty of time for the final stage of the design.

The final stage of the design will be implementation of the discovered specifications into a computer modelling program for better visual aid and ease of modification. This final stage will begin two months before the final deadline of the project to allow adequate time for professional models for analysis. The importance of allowing this amount of time is to allow for any design changes or modelling difficulties that need to be overcome. The computer model will also prove as a means of possible future creation in a factory environment. It is very important for all models to be completed two weeks prior to the 30th October 2014 so that final collaboration can be completed and then final critiquing before submission. Keeping these deadlines will be extremely important to the overall design process and must be kept.

These design plans have been thought through and should be used throughout the project to keep accountable to the deadlines and what is required throughout.

1.5 Outline of the Thesis

The research project through the University of Southern Queensland will investigate and discuss the following information in the chapters below.

CHAPTER 1: Introduction and Project Objectives

CHAPTER 2: Background Information and Previous Research

CHAPTER 3: Methods of Feeding Livestock White Cottonseed

CHAPTER 4: Critical analysis of existing systems

CHAPTER 5: Preliminary Design Considerations

CHAPTER 6: Generation of Conceptual Design

CHAPTER 7: Prototype Specifications

CHAPTER 8: Conclusion

2 Background and Previous Research

2.1 Drought Effected Livestock

The Australian climate is a harsh reality for a lot of livestock producers. Due to the ever changing rainfall patterns, many areas of Australia are currently drought declared. The word 'Drought' can be defined as being an extended or prolonged shortage of an item. In particular to the scope of this project, a period of dry weather or in other terms an extended shortage of rainfall (Dictionary.com 2014). Australia is located in a subtropical area of the world that produces dry, sinking air creating clear skies and little rain (Government 2014a). The current drought has officially been declared the worst of all time according to the Bureau of Meteorology. Below in Figure 2.1 we can see how over the last two years areas throughout the country have been effected by an increasing rate of rainfall deficiency.

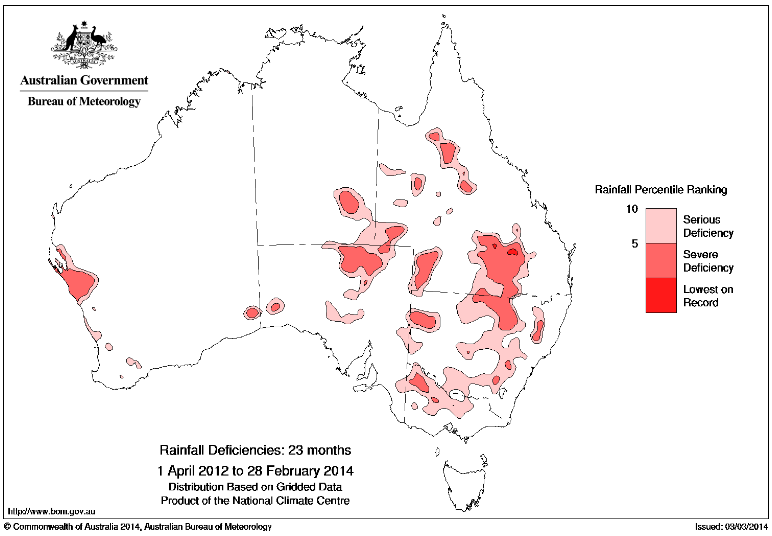


Figure 2.1 - Rainfall Deficiency (Source: http://www.bom.gov.au/climate/drought/)

Queensland alone is currently 80% drought declared as shown in Figure 2.2 below. Throughout the figure it can clearly be seen that 100% of livestock producers land is exposed to these conditions.

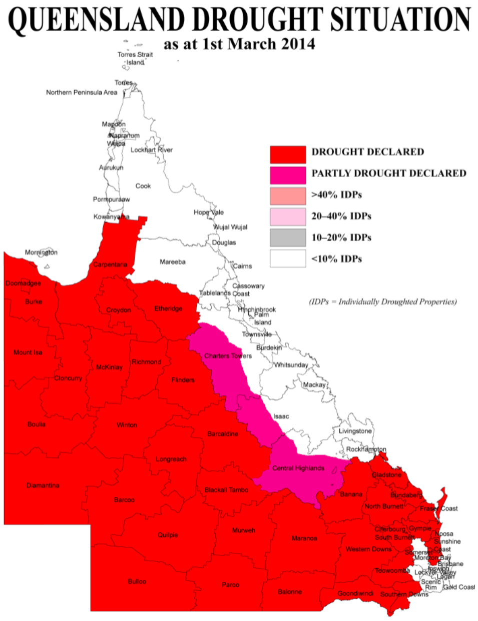


Figure 2.2 - Queensland Drought Situation (Source: http://www.abc.net.au/news/2014-03-07/march-drought-map/5306506)

The Bureau of Meteorology reports that the rainfall deficiencies continue in Eastern Australia, as shown in Figure 2.1, despite easing in Western Australia (Government 2014b). Figure 2.1 shows this very effectively as we can see the majority of the deficiencies are on the eastern side of Australia. This does not at all mean that the remainder of the country is not drought effected but gives an excellent depiction of where livestock producers are being effected the most. This discovery is confirmed by the research undertaken by ABC News which confirms the that the majority of drought affected areas are on the eastern side of the country (Henderson 2014).

The current drought ultimately has an ever increasing effect on the livestock farmers throughout the nation. For the better part of two years producers are faced with tougher decisions to make sacrifices to make ends meet in the harsh conditions. For most livestock producers the source of feed and water for their cattle becomes a task that requires lots of man hours and lots of money since they cannot rely on the natural source of feed from their wilting properties.

With this increasing deficiency of water to sustain natural feed for livestock, producers need to turn to alternate methods for sustaining the health and wellbeing of their livestock. This prompts sourcing of external feed options likes of grain, lick blocks, hay and white cottonseed just to name a few. One of the more effective feed products being sourced, and currently being used throughout the nation for this purpose, is White cottonseed (WCS).

This by-product, of the cotton ginning process, is used for the purpose of balancing the livestock's diet to maintain a reasonable state of health.

Not only is their health important to producers but their weight as well. Cattle grazing unimproved pastures during the drier months of winter and spring can cause considerable live weight losses. This will occur unless a dietary supplement is put into action to meet the protein and energy demand of the livestock (McLennan et al.). This is confirmed by (Wood et al.) who says that protein supplementation improves the nutrition of cattle grazing low quality pastures by increasing dry matter intake which in turn provides the livestock with the required glucose and amino acids. This confirms that it is important for producers to continue supplying their livestock with the correct nutrition so they remain healthy and sustain their current weight.

Ultimately the weight of the beast is what makes the producers the money and maintaining their weight throughout not only the drier months of the year but also the current drought makes implementation of such a product a must for all producers. Implementing a product like WCS needs to be done so carefully and with planning on the producers behalf. There are guidelines that need to be followed and cautions that need to be taken into consideration.

2.2 Feeding Livestock White Cottonseed

WCS has been fed to livestock at an ever increasing rate over the past 20 years. The percentage of the ration fed to the livestock varies dramatically due to the application at hand (whether the cattle are dairy or beef etc.). In the case of this limited project the application is Beef cattle and therefore the application will take this into consideration. With this scope in mind there are some limitations that were discovered through (Blasi & Drouillard 2002) that there are four main guidelines that need to be considered when feeding WCS to beef cattle, these are;

1. Feed only gin-run cottonseed, meaning the seed is whole, non-delinted (seed is still covered in the cotton lint) and untreated.
2. Feed only dry seeds that are free from mould and any other degradation effects. The seed should be free of foreign debris, clean, white to light grey in color and should rattle when shook.
3. Grinding whole non-delinted cottonseed does not improve the feeding value.

4. Whole cottonseed should be hand-fed as it does not flow well through self-feeders

Further research discovered from (Lane 2001) there were additional guidelines to the ones listed above.

1. Do not feed WCS to young bulls as this can possible cause temporary infertility
2. Consumption of WCS should be limited to 2.7 kg/day for mature animals and 1.4 - 1.8 kg/day for weaned calves. WCS is not recommended for young calves as overconsumption can cause scours (diarrhea). This is a common cause of calf death as they lose too much fluid from their body causing rapid dehydration (Today 2011).

These guidelines should be followed and considered important in the feeding of WCS. However point No. 4 prompts the issue of WCS being difficult to handle and the problem to be tackled by this project and will not be a crucial factor in further discussion.

To meet the guidelines listed above WCS should be treated well during the storage stage. To effectively meet No. 2 it is important for WCS to be stored in an environment that has a moisture content less than 10% (Willcut, Herbert M., Mayfield, William D. & Valco, Thomas D. 1997) so that the product does not accumulate mould. If this is not taken into consideration the mould can produce risks of Aflatoxin. Aflatoxin, a naturally occurring contaminant, can cause liver problems and various other health effects in livestock so it is important for producers to monitor this so their livestock does not consume these anti-bodies. It is also important to keep the WCS sheltered from rain and if possible cycle air through the seed to keep it dry and cool. This can be achieved through the use of Aerators or continually mixing the seeds.

WCS has some incredible nutritional benefits to livestock and can be of great value to drought affected livestock. According to (Stewart 2010) WCS is a unique feed that has to ability to adequately supply livestock with Fibre, Protein and Energy. It is also confirmed by (Blasi & Drouillard 2002) this WCS is a great source of these nutritional aspects and should be used in accordance to these properties to benefit the livestock. WCS is a nutrient dense feed in fibre, energy and protein that when digested by livestock, causes a slow release of nutrients and makes the feeding more beneficial (Blackwood 2007).

It is important for producers to be aware of the benefits and cautions to feeding their livestock WCS. It is also extremely important that the rations are meeting the number of cattle and not under or over feeding them. Keeping track of the amount fed to the livestock is of key importance to their health. This prompts research into a variety of aspects that are important for this project to discuss including rations, nutritional value and cost, just to name a few. It is important for these aspects to be covered as it will give adequate background into why feeding WCS is a viable option and also make producers aware of the cautions. The process of feeding WCS to livestock can be completed by a variety of techniques that will be covered in chapter three. However it is very important to know how to effectively feed livestock WCS and the benefits of doing it during drought seasons. There are some main areas of concern that should be discussed to better explain the benefits and the disadvantages of undertaking such practices. These will include:

1. Nutritional benefits and cautions for livestock
2. Cost effectiveness to producers
3. Sustainability and availability of WCS supply

2.2.1 Nutritional benefits and cautions to Livestock

WCS is the seed produced as a by-product of the cotton ginning process, it is high in fat, protein and fibre. The nutritional benefits of feeding livestock this product is extensive and should be utilised effectively. In Figure 2.3 we can see the nutritional composition of WCS, this document can also be found in Appendix B on Page 7.

Table 2. Nutrient composition of cottonseed and by-products resulting from the cottonseed crushing process.[a]

Nutrient	Whole Cottonseed	Cottonseed Meal Expander Solvent Extracted NRC[a]	NCPA[b]	Cottonseed Hulls NRC[a]	NCPA[b]
Dry matter, %	92	91	89.1	91	89.9
Crude protein, %	23.0	45.2	47.6	4.1	5.0
NEm (Mcal/lb) [b]	1.10	.83		.31	
NEg (Mcal/lb) [b]	.76	.54		.07	
TDN, %	95	76		42	
Acid detergent fiber, %	20	17	17.3	64	67
Neutral detergent fiber, %	40		24.5	90	86.9
Crude fiber, %	20.8	13.3	11.2	47.8	48.6
Ether extract, %	17.50	1.6	2.2	1.7	1.9
Ash, %	5.0	7.1	7.5	2.8	2.8
Calcium, %.	16	.18	.22	.15	.15
Phosphorus, %	.75	1.21	1.20	.09	.08
Magnesium, %	.35	.59	.66	.14	.15
Potassium, %	1.21	1.52	1.72	.87	1.13
Sodium, %	.31	.05	.14	.02	.01
Sulfur, %	.26	.28	.44	.09	.05
Copper, ppm	54	22	12.5	13	3.6
Iron, ppm	151	228	126	131	30.1
Manganese, ppm	10	23	20.1	119	16.8
Molybdenum, ppm			2.5		.37
Zinc, ppm		68	63.7	22	9.9

Figure 2.3 - Nutrient Composition of Cottonseed (Source: (Blasi & Drouillard 2002))

The document produced by (Blasi & Drouillard 2002) shows us that the Crude Protein is around 23.0%, the Crude Fibre is at 20.8% and 16% Calcium. These figures are comparatively accurate to the figures of (Riverina 2013) which states that WCS has a Protein percentage of 21.00%, Fibre percentage of 24.00% and a Calcium percentage of 0.14% however the calcium figure of 16%, from Figure 2.3, begs the question of whether this source has an error in the table. Further consultation into the research of (Florida 2013) confirms this with their reading of an average calcium percentage of 0.2% meaning the correct reading from (Blasi & Drouillard 2002) should be 0.16% Calcium. The research of (Blackwood 2007) confirms that the Calcium percentage is around 0.15%, giving an effective range of 0.14% to 0.2% for accuracy. (Blackwood 2007) states that the Crude Protein can range for a low of 12% up until 22% with relative error. These properties are only the major factors being considered, any further information needed can be sourced from Appendix B.

Due to these nutritional benefits, WCS is the whole package, providing livestock with a balanced amount of protein, fibre and calcium. Producers around the world call WCS a cost-effective "triple nutrient" (Cottonseed 2014). However with every feed product there is a limit to the amount that can be fed to the livestock and these cautions need to be carefully considered in the calculation of an appropriate diet.

One of the major cautions with WCS is the Gossypol content that is present. Gossypol is a toxic compound found in the cotton plant, it is particularly concentrated in WCS. Gossypol exists in two forms, free form and bound form. In other terms the free form is the toxic and bound is non toxic (Morgan 2013). The amount of free form Gossypol is important for producers to be aware of since it can be lethal to younger animals and effect older livestock depending on the amount present. Gossypol is measured in a percentage (e.g. 0.02%) and in a term Parts Per Million (ppm). The conversion is simply 0.02% is 200 ppm (Morgan 2013). WCS contains the most amount of free form Gossypol compared to Cottonseed Meal etc. It is important for producers to have any bulk WCS tested for Gossypol so they can effectively create a diet that will not be devastating to their livestock.

The amount of free Gossypol tolerable in livestock varies with the age of the animal. Because the toxins effect the heart and liver the most younger calves are more susceptible to the toxic effects than more mature beasts. Calves in particular cannot be exposed to WCS containing over 100 ppm while adult livestock can handle 400 - 600 ppm (Morgan 2013). If the Gossypol content increases than these limits death or sickness will occur. The general sickness symptoms in adults is weakness, loss of appetite, blood in urine, reproductive problems and difficulty breathing (Morgan 2013). Therefore it is important for livestock producers to keep a close eye on their livestock when undertaking such feeding procedures and taking fast action if symptoms begin to occur.

2.2.2 Cost effectiveness to producers

An important aspect to undertaking this approach of feeding WCS to livestock is ultimately whether the approach is cost effective to drought effected producers. By sourcing three prices of WCS on the current market and comparing these costs to that of other feed methods like hay or other grains it can be summarised how cost effective WCS is to producers. By consulting (Cotton 2014) website and contacting the head of pricing the following discoveries were made:

<u>Price per tonne (current season)</u>

Bulk Purchase - $445.00 + GST

Bagged Purchase (30kg Bag) - $20.60 Per Bag

<u>Price per tonne (drought season)</u>

Bagged Purchase (30kg Bag) - $26.45 Per Bag

Bulk Purchase is hard to estimate due to fluctuating supply and demand

The price of WCS varies according to the season and availability of cotton itself. During the drought season the availability is lower due to the fact of little cotton being grown and also that the average producer needs to turn to a product like this to meet the demands of his livestock driving the companies to increase the price so that they can still turn profit off the amount of WCS they handle.

Of course there is more than one option to feed livestock during the drought season. Some other dry feeds include grain, hay and forage. Of course during the dry seasons forage sorghum or oats can be hard to come by however if the rain occurs at the right time then this can be an option for producers. Oat seed can be sourced at approximately $XX per tonne and of course has planting costs on top of this expense.

Grain is another excellent source of dry feed and some producers that grow crops like sorghum plan ahead during the summer season and keep some grain on hand for the feeding of their livestock. One way is to use a hammer mill and create a dry combination of different grains and a supplement powder. These powders are used to benefit the livestock nutritionally and create a stable feed. The use of a hammer mill is to evenly distribute the crushed grains and the supplement throughout so that the product being fed out is of even consistency benefiting all the livestock. The process occurs regularly during the drought season if the producer has the milling equipment and the availability to the grain they want to feed. If the producer has left over grain from the summer season then costs are reduced greatly as they only need to source supplement mix and an alternate grain to mix. The reduction of costs is the greatest goal for any producer during this time. Of course this process can use WCS and sorghum for example to create a nutritional gold mine for producers as they can benefit from the value of WCS but don't need to source as much. When mixed with another dry feed the product can last extensively longer and this reduces the cost overall.

Another option for producers is to feed livestock hay products. This feed is simply the left over plant from the summer crop which is cut and gathered by a series of three processes:

1. Slashing or mowing down to ground level
2. Creation of wind rows which is the single file line of mowed crop to be gathered by the bailer
3. Baling: The process where a machine gathers all the mowed crop and creates a compact square, rectangular or round bale of crop that can be then fed to livestock by a variety of ways

Some of the most common feeding techniques include bale feeders, shown in Figure 2.4. These are simple constructions made to house the hay so that it remains in a confined area and the livestock know where to find it.

Figure 2.4 - Hay Bale Feeder (Source: http://www.haysaverfeeder.com/images/hayConserverBaleFeeder-Quotes.jpg)

Other methods are simply dump the hay out in strategic spots scattered around the property. Most producers use the feeder method as it draws livestock into a confined area, usually where the water and shelter is. Hay bales can usually be sourced from a variety of sources including surrounding producers or they can be created on farm by the producer from the remains of the previous crop.

There are three major types of hay that are predominately used to feed livestock. These are Lucerne, Straw and Barley. They all vary in price with the changing seasons and the availability of crops to create them however the average costs are listed below:

Lucerne Square Bales - $8.00 - $20.00 (approximately 15 kg per bale) average of $14.00

Straw Round Bales - $60.00 - $100.00 Per Bale (approximately 500 kg) average of $80.00

Barley Square Bales - $11.00 Per Bale (approximately 15 kg per bale)

As shown by these figures the average costs can be used to effectively compare the costs of feeding hay with the implementation of dry grains like sorghum/wheat/barley etc.

It is to be noted that these other means of dry feed can be usually sourced from the producer if plans are made previous to the winter season or before the drought season begins to truly set in. If producers can plan ahead to reduce costs and increase the sustainability of the livestock's health then this will benefit them greatly. This raises the question on whether WCS itself can be sustained during the drought season or whether a producer should plan ahead for his livestock.

2.2.3 Sustainability and availability of WCS supply

As previously discussed WCS is sourced predominantly from cotton gins, as it is the by product of the ginning process. The availability of WCS is therefore very dependent on the Cotton season and the amount grown by producers in the surrounding region. Since the amount of WCS is relative to the amount of Cotton produced that season, the amount of WCS available is always changing. However there is never a lack of the product. Since the cotton industry is ever expanding with the peak demand of the world today, cotton has become an important crop for producers to grow since pricing can be much greater than grain. Producers usually grow cotton over the cooler seasons making this crop excellent for a second income source for that year. The rewards of this crop are greater however the costs to produce increase as well. The rewards from Cotton production causes producers to create more effective processes to grow cotton during drought seasons. Good news for the use of WCS since producers, even through drought seasons, still grow cotton. This makes WCS very sustainable throughout the drought season but costs do vary with the change of availability. This said, the cotton industry is one of Australia's largest rural export earners and has increased its average production value from 7.3 Bales/Hectare to 8.7 Bales/Hectare in the past five years (Australia, C. 2014). This means that the sustainability of WCS throughout the year is growing and the availability is only increasing as producers are finding more effective ways to grow cotton with the little land that they have access to.

Queensland Cotton is one of the major suppliers throughout the region for cotton by products as they predominately control the market. As previously discussed the pricing can vary depending on availability making the costs hard to determine. However with the average costs in and out of drought season rough estimates can be created to help producers plan a budget.

WCS is very sustainable throughout the dry seasons due to the high production rate in Australia. Producers wanting to source this product can simply contact Queensland Cotton to find the nearest available stockpile.

2.3 Applicable Scenarios for Design Limitations

The design of a device that is to optimise the process of feeding out WCS needs to be limited to a set of scenarios to better analyse whether the device can be used in a large and small scale. The following three scenarios will be used in comparison to one another to better analyse the device and complete an accurate critique process. Some major aspects of these scenarios is to identify whether small and large scale feeding can be completed by the same device without varying the cost to great.

The following three scenarios were chosen after the consultation of various beef livestock producers in the surrounding areas and acknowledged throughout. These three scenarios give a good guideline on the number of cattle that needs to be fed.

1. Hobby Producer - After consultation with local producers the hobby livestock herd is approximately thirty head. This size is a very small scale that is designed for small scale investment or better utilization of available land. The benefit to having a small number is so that producers can keep the costs low while still making a small profit margin viable enough to continue such an operation. Some benefits this causes to producers properties is a healthy regrowth of grazing land. By having beef cattle grazing on their land can increase the health of soil from the natural fertilization. As found from (Blackwood 2007) it is recommended for drought effected livestock, that are being fed a WCS only diet, should not be exposed to more the two and a half kilograms per head per day (2.5kg/hd/day) This means that on average, and at a maximum, the producer needs to feed:

   (2.5 kg/hd/day) * (30 hd) = **75 kg**

This value is fairly low and could easily be fed by hand quite quickly, however the aim of this research project is to create an automated device to do this. To meet the requirements of this scenario the device should be able to store and successfully feed out 75 kg of WCS into a feeder or onto the ground as per the producers demand. (Blackwood 2007) also mentions in his discussion that younger steers or weaners cannot be fed over one (1) kg/hd/day. So depending on the age of the livestock will change the amount of feed required. However is design considerations takes into account the maximum amount of feed needed to be distributed then the design will meet all criteria.

2. Small Scale Operation - A small scale operation is most likely found further west than the likes of hobby producers. These farmers are large enough that they make most of their money off such an operation. The typical size of a small scale operation is 300 head, and can often be found in regions west of Dalby. These properties can effectively bring in a substantial profit so that the operation can continue throughout the year without any other need of income. However after consulting a small scale producer, it was discovered that in drought times other means of income needs to be consulted like grain crops (Mulhare 2014). Although some years this needs to happen, small scale operations can be effective in creating a profit for the producer.

   (2.5 kg/hd/day) * (300 hd) = **750 kg**

   Therefore for a small operation the device should be able to handle roughly one (1) tonne of product so that the design can handle more than required of it. These considerations will limit the product to a livestock cap of 400. This is of course how many livestock the device can feed in one pass without being filled again. Meaning producers can head out into the paddock with a full load for their cattle and do not need to refill numerous times. If a stock figure exceeds this a substantial amount then a third scenario will have to be considered.

3. Beef Abattoir - According to JBS Australia, the average number of beef livestock held on premises is approximately 8000. Quite a jump from the small scale operation but will prove to be a valuable investigation into the amount of WCS needed to be fed to a huge operation like this one. Of course the amount of feed that is needed escalates quite a lot when comparing to an operation of this magnitude but it is important for this project as the design, once optimized, may be

able to be scaled to suit such an application making the design feasible for even operations like the beef abattoir.

(2.5 kg/hd/day) * (8000 hd) = **20000 kg = 20 tonne**

Of course major feedlots would not rely on a completely WCS diet but would mix with a variety of other dry feed to meet the demand of the livestock being handled.

With the limitations of these scenarios, the design can be better created to suit the applications of the real world and can be optimised to benefit every type of producer. These scenarios will give a scope to the design specifications and limit the design to specific dimensions.

2.4 Previous Research of Automated WCS Feeder

It is important to consult various sources to compare and analyse the existing market of automated feeders. In particular it is crucial to find any existing systems that meet the requirements of this research project and how it can be optimised to benefit the producer. By creating a list of existing systems and the current use they have in the agricultural industry, this project can utilise the existing research in this market and try to better solve the problem at hand.

After extensive research into the existing systems that have use in particular to this project it was discovered that not a lot of individuals have been using automated feeders for cottonseed. Due to the physical nature of the product and the challenges this causes, manual methods are of course more effective and beneficial. However a new specific design for this purpose may just be able to be created from use of all previous methods combined.

One automated feeder that is currently being utilised in the United States, is one created by (Feeders 2012). The company trades as T & S Feeders which utilise a simple mechanical system that portions out feed piles to cattle but also has the ability for a constant flow for use in filling feed troughs or even storage bins. The schematics of this project state that the device must be able to be mounted onto a utility or by the use of a trailer. The product created by (Feeders 2012) meets all of the requirements of the project at hand and one of their devices can be seen in Figure 2.5. This is one of the smaller devices they currently produce however the design is very applicable to the design required by this project.

Figure 2.5 - Trip Hopper Feeder Small Truck Model (Source: http://www.tsfeeders.com/graphics/jr_01.jpg)

This device works by one powerful 12V motor that drives a chain as well as a swing arm that is rotating in a circular motion. On the end of each arm is a wheel that runs down a lever pushing the trap door open, in turn dropping the feed out onto the ground or into the trough. The trap door is opened twice per rotation of the motor which is reduced to quite an appropriate speed. However the amount of feed is controlled by the conveyor running along the bottom of the storage tank. This conveyor takes the product to the end where the chute is however there is a gate controlling the amount passing through. This gate is on a vertical axis where the feed passes under it at a certain flow rate. The lower the gate the less feed travelling into the trap door compartment. Once the feed is through the gate the end of the conveyor is met and the feed falls into the trap door compartment awaiting the door to open. The accuracy of the machine is not 100% as there is always some feed catching in the trap door or not enough feed coming under the gate however the error is minimal in the scheme of the application. Some different devices are shown in Figure 2.6 and Figure 2.7 to give examples of the different sizing options this device can be utilised in.

Figure 2.6 - Trip Hopper Feeder Large Truck Model (Source: http://www.tsfeeders.com/graphics/pu_01.jpg)

Figure 2.7 - Trip Hopper Feeder Trailer Model (Source: http://www.tsfeeders.com/graphics/tr_01.jpg)

These devices have incorporated mechanical systems that ultimately work together to portion out feed of the desired amount. Perfect for the application with WCS however critical analysis of the system should be undertaken to see whether the conveyor and gate system will effectively proportion WCS to the desired amount.

Another approach discovered is of similar nature where a feed dispenser is used however the design is slightly different. These dispensers use augers to feed the product out through a small opening at the end where a chute is used to guide the feed. Below, in Figure 2.8, is an example of the device.

Figure 2.8 - Bar6 Feed Dispenser (Source: http://bar6.net/feed-dispensers/)

(Manufacturing 2014) Bar6 have utilised a similar approach to T & S Feeders however these dispensers are using augers in place of conveyers. Another different approach used here is that the feed dispenser relies on the auger turns to calculate the amount of feed exited, unlike the T & S Feeders which use a gate system. Ultimately both approaches are accurate in dispensing the feed but the conveyor/gate system remains simplest since all systems can remain running throughout the process. Alternating whether the motor is running or not can complicate the system as use of relays and timers is needed to accurately portion out small doses of feed that is necessary when feeding WCS.

German manufacturers (Lengerich 2014) utilise grain mixers that claim to handle a variety of materials. The trailer type machine uses a combination of augers and conveyors to mix the product and move the product out the exit chute. In an example of this system can be seen unloading feed into a trough for the livestock. By using such a combination the design become applicable to the project at hand simply because augers could be utilised to separate and keep the WCS moving during transportation which would limit the bondage to one another. Since the product would be loose it could then be fed onto a conveyor for exiting purposes. An appropriate approach for such a problem that needs to be critically analysed in final design creation.

Figure 2.9 - V Mix Plus (Source: (Lengerich 2014))

Another found device that utilises augers to shift the material is created by (Ranch 2014). This can be seen below in Figure 2.10. These feeders are American made and boast to be leaders in heavy duty farming equipment.

Figure 2.10 - Heavy Duty Cube Feeder (Source: http://tarterusa.com/tarter-products/heavy-duty-cube-feeder/)

This device, like previous feeders, are more appropriate for small pellets and ground feed and are currently not being used for the application this project desires to meet. The benefits of this system are very similar to that of the previous systems discussed as the design is very similar to that of (Manufacturing 2014) which uses a chute to guide feed out of an auger exit. Unlike the Bar6 Feed Dispenser, the Tarter Heavy Duty Cube Feeder seems to be built of a higher quality and houses a much more powerful electric driven motor. These motor has the required wiring for plugging into a trailer power outlet or wiring into the cabin of the truck or utility.

The main overpowering advantage to the Tarter system over the Bar6 is the more professional quality of build making the Tarter a much more appropriate heavy duty design for the farming industry.

Another final design discovered is a system created by Commander Ag Equipment (Agquip 2014). Similar to all the design discussed previously the mobile feed out bin boast a new approach to the automated feeding process. Shown in Figure 2.11 is the approach where the driver controls the chute opening and closing from the comfort of the driver's seat.

Figure 2.11 - Mobile Feed Out Bin (Source: http://www.commanderagquip.com.au/products/1ton-silo-mobile-feed-out-bin-with-tarp)

This design shown above is utilised mainly in the feeding out of grain products since there is only the use of gravity for the movement of the product from the device. This design cannot fully be utilised by this project however the levering system to operate the feed door may prove to be a usable factor. Since the WCS needs to be fed out at a controlled rate, the use of a manual adjustment like this could prove useful in the final design. The other useful idea here is the mounting approach, they use a plate on the device legs where the legs can be fastened to the utility tray. This approach seems very useful throughout agricultural applications. This design has a few features that should be considered as well throughout the final design creation and conceptual drawings.

These are the most extensive approaches found that are currently being used in the industry today. None have been proved to successfully handle WCS however they seem to all use similar approaches and mechanical systems that could be utilised in the final design of an automated WCS feeder.

2.5 Conclusion

By consulting a variety of sources and gathering appropriate information the benefits of feeding WCS to livestock during drought seasons proves to be very effective. The cost and sustainability of this product makes it very applicable in such applications. Feeding out such a product can prove to be a challenge to producers. Through the research into existing systems it can be seen quite clearly that automating the flow of such a product is challenging and has yet to be mastered. By researching into the current methods of feeding livestock it may be possible to draw some existing systems into a new conceptual design.

From this research of current methods, popular existing systems can be drawn out and critically analysed on their possible application into the project. The aim of this project is to effectively create an automated system that can create an even flow of WCS seed through some system which may possibly simply be a modification of an existing system used currently which is why extensive research into current methods needs to be undertaken.

3 Methods of Feeding Livestock White Cottonseed

The process of feeding out White Cottonseed (WCS), as discussed previously, is a task that can be undertaken by a variety of methods. This chapter will cover the variety of manual/automated methods and the use of agricultural machinery. By sourcing these multiple feeding options it will become clearer on the most used approach currently and how it is possible to optimize this method. By consulting multiple resources and accurately comparing each method with each other, we will get a better understanding of how the farmers approach this problem.

3.1 Manual Feeding Process

Manual handling of WCS is by far the most effective process that is currently used by the majority of farmers according to John Bowman of the Department of Primary Industries (Bowman 2014). This fact is confirmed by a multitude of sources that have been found throughout the research process. Also by consulting a small number of local livestock producers, "manual handling of cottonseed, although physically demanding, is by far the cheapest method that farmers are currently using" says Denis Wooldridge, a farmer located in Queensland's Darling Downs. "Drought stricken farmers are usually facing financial hardship, so the choices of getting livestock feed becomes more and more limited." (Wooldridge 2014). When manual handling WCS, a grain shovel or bucketing, is usually the recommended approach (Blackwood 2007). Due to the physical properties of WCS auguring the product proves difficult making manual shovelling the current most effective approach (Department of Agriculture 2012). Even a study undertaken by (Stewart 2010) and (Lane 2001) discuss the difficulties that arise when handling this product, making shovelling the most cost effective approach. Figure 3.1 shows a grain shovel that is the tool most producers use to handle WCS manually. After consulting a variety of companies that stock these devices, they vary from \$20 - \$40 AUD depending on the quality of build and the brand. A very cost effective tool for this application.

Figure 3.1 - Grain Shovel (Source: http://www.shtfplan.com/wp-content/uploads/2010/10/shovel.jpg)

Farmers have realized the problem with the handling difficulties and ultimately settle for the manual method as it is cost effective and easy to source the tools required.

3.2 Agricultural Machinery Feeding Process

Figure 3.2 - Front End Loader (Source: https://www.deere.co.uk/en_GB/media/images/our_company/news_and_media/press_releases/2013/nov/John_Deere_5100M_tractor_H260_front_loader.jpg)

Although the manual approach to feeding out cottonseed is excellent and meets all the requirements, the scale of operation often cannot be met by simple manual methods. The second method that currently is being used is front end loaders. As shown in Figure 3.2 we can see such a device in operation. Essentially this method is an upscale of the manual method by using a mounted bucket that can handle up to 0.86 m^3 (Deere 2013b) for a standard bucket attachment. These standard attachments are by far the most common for the use when handling products such as WCS. The device itself is hydraulically operated and can be attached to a variety of different agricultural machines. The most common is the attachment to a tractor which creates a very practical tool that can be used for a multitude of tasks not only the bulk handling of cottonseed. This benefits producers as the device is universal making a purchase viable. The purchase of such an attachment for a tractor would be around $2239.00 (Travers 2014) for the bucket alone and can easily be sourced from any John Deere representative or dealer. The full hydraulic set up for the machine itself can be up to $22,000.00 (Baines 2014) and can be mounted onto a variety of machines. This begins to make the costs of this approach mount up and needs to be considered highly against other options before a decision is made by the producer.

The handling of WCS with a front end loader adds extra cost, as there is a need for fuel to operate the equipment. Added costs can deter producers that are facing financial hardship during the drought season and one of the major aims of this project is to reduce cost. As mentioned earlier the addition of this running cost is met with the benefit of adding a very useful piece of equipment to the producer’s property and can be considered beneficial.

3.3 Troughs and Feeders

Alongside the manual method and the use of agricultural machinery there is also the use of feed troughs. These devices come in a variety of different builds that vary from automatic feeding of the grain to open air feeders. Open air is simply where the feed is loaded into a container situated on the ground and the livestock can help themselves to as much feed as they want. Open air feeders are not used to designate a specific amount of feed to the livestock. It is important for producers to be aware that this method of open air feeders can cause nutritional issues in their livestock if not monitored effectively. The exposure of too much WCS can lead to problems like scours and other medical issues which were covered in chapter two.

One of the major advantages to using an open air feeder is due to simplification and cost effectiveness. If the producer does not have an extensive head of cattle then the use of such troughs is effective enough as the rations are not as important as with a large scale feedlot. An open air feeder can effectively be created from all sorts of containers which benefits producers by cost reduction. Another advantage of the open air feed trough is the multipurpose of the trough. Producers can use these troughs for storage of water and other feed products not only WCS. Shown below in Figure 3.3 is an example of an open air feeder used by producers.

Figure 3.3 - Open Air Feed Trough (Source: http://www.lumber2.com/v/vspfiles/photos/BW-25564F-2.jpg)

A major disadvantage to this method of feeding out product is the lack of protection from the elements. The feed is exposed to elements that will ruin the integrity of the product and fail to provide livestock with adequate nutrition. In particular with WCS, when the product becomes wet, the lint surrounding the seed absorbs the moisture which causes mould and degradation to set in very quickly. This process creates a problem and if the integrity of the feed is to remain adequate for a period of time then this approach would be less than appropriate.

Another type of feed trough that are extensively used throughout agricultural properties are grain feeders. An example is shown in Figure 3.4 of a grain feeder used by producers for the monitored feeding of grain products.

Figure 3.4 - Grain Feeder (Source: http://www.westbrookengineering.com.au/wp-content/uploads/2009/03/westbrook-0083-300x225.jpg)

These feeders, unlike open air feeders, provide protection for the feed from the elements and provide a simple regulation process to limit the amount of feed discharged. The basic design of these feeders is to keep the feed from being compromised by weather and to also limit the amount of feed that is being eaten by the livestock. This is achieved by a small long opening which the feed falls through. The grain is limited to the top of the opening as no more grain can fall into the feed chute as there is effectively no room remaining. When the livestock begin to lick the feed out, more feed falls to replace it. The amount of feed that falls can be maintained by the size of the opening at the mouth of the feeder which can be manually adjusted by the farmer (Feeders 2014). These are the most common devices used for smaller and intermediate size livestock operations as the number of cattle that can be at one feeder at a time is very limited. Although the disadvantage for such a device is the cost compared to simple open air feeders, the producer will potentially save money in the long run. This potentially can happen through the amount of feed lost due to weather damage. Another advantage to using such a feeder is that they can maintain sufficient feed for a longer period of time, reducing the number of man hours to keep a sufficient supply of the product to the livestock.

3.4 Mill Processing

One special way that producers feed WCS to livestock is by creating a more manageable product. This approach utilises a machine called a 'Hammer Mill' which effectively pulverises the product down into an edible powder. This process happens quite a lot throughout the farming industry since the powder can consist of a variety of ingredients (e.g. Grain, Hay, WCS, Dietary Supplements and a variety of other products). A mountable hammer mill is shown below in Figure 3.5.

Figure 3.5 - Stationary Hammer Mill (Source: http://cfnewsads.thomasnet.com/images/large/503/503663.jpg)

As seen above in the figure, the product is fed into the mill via the chute and pulverised by the rotating hammer system. The feed is then exposed to a screening process where the product only exits the hammering chamber once it is at a particular size. This helps the producers control how fine the product is after the process is completed. This process is very beneficial to the producers in a variety of ways since it is very controlled and creates a feed that is of even consistency and mixed well. Producers can effectively control the amount of WCS fed to the livestock but the addition of other ingredients causing a rise in costs and requires these products to be available which isn't always the case.

Since this project is paying particular attention to the WCS as a raw product being fed out to the livestock this process will be ignored.

3.5 Automated Feeding Process

The major focus of this research project is the current automated feeding processes that are being utilised by livestock producers worldwide. The problem that prompted this research was to optimise the feeding out of WCS and to design a device that could meet all design criteria. It is important to consult as many different devices and methods to automate the process and create a more effective way of meeting the demand for an easier approach for producers.

There are multiple methods that can possibly be implemented into the design of an automated device for feeding WCS. They can be separated into six categories which can be written as the following:

1. Screw Conveyor
2. Conveyer Belt
3. Chain Bed
4. Automated bucketing system
5. Gravity Fed
6. Pneumatic and Hydraulic System

This list consists of the elements that could potentially be used in automated devices for the purpose of meeting the project objectives. It is important to source current devices to adequately compare what is available already on today's market and potentially source some current prices that could be beaten during this project. Ultimately the cost needs to be reduced making a device that is affordable to producers that are currently drought affected. Each of these categories will be analysed of how it could possibly be used in the final design and the current uses for it in the field.

3.5.1 Screw Conveyor

Screw conveyors, a specific type of Auger, are used by agricultural producers not only in Australia but worldwide. They have been used for many years in the seed industry as they are a great way of transporting seed effectively from where it is currently being held to an external container etc. The cross section of a typical screw conveyor can be seen in Figure 3.6 below.

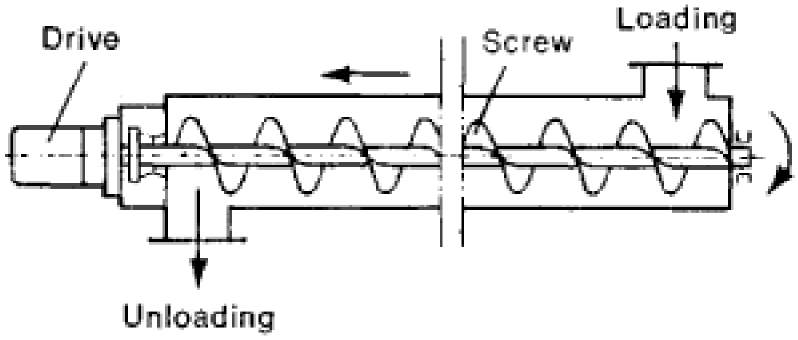


Figure 3.6 - Screw Conveyor (Source: http://img.tfd.com/ggse/e0/gsed_0001_0012_0_img2865.png)

As the seed falls into the loading area the screw conveyer, which is rotating, takes the seed towards the left since the spiral walls push it along its travel. The seed then reaches the left hand side which is the unloading area where the seed falls out and down a chute or directly onto the next process. The benefit and use of these augers is that they can move quite a large amount of seed at a pace relative to the driving force. This helps producers quickly move seed from one area to another without the use of any manual labour.

Another benefit to screw conveyors is the ability to move grain up an incline. Since the screw mechanism does not rely on gravity, the seed can be moved practically at any angle up to 90 degrees. Of course the limitations of this is how much seed can be fed into the barrel (length of housing containing the screw conveyor) as the angle increases the torque required to screw the seed up the barrel increases as well due to the gravitational effect on the seed.

Sourcing screw conveyors is very easy as they are one of the most utilised way of moving seed on agricultural properties. Due to the amount being used the price for them is relatively conservative. An initial consult with Ahrens Group led to the discovery of a simple screw auger flight for the application at hand would cost around $2500.00 AUD to manufacture. Of course this figure is an initial rough estimate and would change with the specifics of the project however this gives and appropriate guideline for initial comparison. (Rolston 2014)

Screw conveyors are a very applicable device that will need to be adequately analysed in the design stage of this project. Due to their availability and cost effectiveness they could possibly be utilised in such a device. Due to the fact WCS has some interesting physical features and the current lack of practical application for this purpose, further analysis into the way it reacts when being transported by the use of screw conveyors is a must.

3.5.2 Conveyer Belts

Conveyor belts are utilised in an extensive amount of industries worldwide. They consist of a driving force that rotates the y axis of the belt causing it to move in an x direction. The set up of a simple conveyor can be seen in Figure 3.7. The belt is usually made of a rubber substance as this can be stretched tight around the driving device and also because it can be easily manipulated to suit a variety of different applications.

Figure 3.7 - Conveyor Belt Assembly (Source:http://www.heenaindustries.com/wp-content/uploads/Belt-Conveyor.jpg)

Some of the many uses include factory operation (e.g. Mail sorting, Bottling factory, airport luggage shifting etc.) where conveyor belts are used to move items quickly through a process or from point A to point B. The speed that comes with using conveyors out weights all other options since they can be created at any length practically and are very cost effective in optimising factory operation.

Another use which is applicable to this study is the use of conveyor belts in grain moving. Since WCS is the product needed to be shifted these agricultural conveyors may be very useful in the creation of an automated device. The current use of conveyors in agriculture is the in the 'Grain belt' as the industry calls them. They are essentially the same design as a screw conveyor but the grain falls onto a belt that is moving instead of a screw conveyor. A few particular companies that are utilising these Grain belts are Brandt (International) and

Austech Toowoomba (Local). These reputable companies see the benefit in using the conveyor belt in their devices as they can quickly transport a lot of grain effectively. (Brandt 2013)

The conveyor system is ultimately a more expensive approach due to the added designing of the system for it to interact well with each other. After initial consultation with a reputable company on the costing of such a system, it led to the discovery of how much a simple system can be. The initial costing for a conveyor belt system for the feeder would reach approximately $4000.00 AUD including all rollers and belt (Rolston 2014). The only other expense on top of this would be the cost of the electric motor to be sourced in the final prototype analysis. These prices are subject to change and give a good number comparison for final analysis.

Another possible modification to a conveyor system is the implementation of a remote system. By implementing a remote controlled chain bed producers can control the amount of seed being fed out to the livestock. Currently this is being utilised in the cotton industry already in a number of applications. The Cotton Picker and the transport from the Picker to the 'Module Builder' use remote chain beds to control the unloading process otherwise if the cotton is off loaded to quickly, due to the bondage of cotton lint, the cotton will remain as a lumped mass and can spill over. However the application for the WCS feeder would be for the producer to have unloading control for the livestock but would not be able to correctly ration the feed like in other approaches. The producer would simply have to judge the amount feed being off loaded.

A further application of the conveyor belt is the chain weave belt like the one shown in Figure 3.8. These are utilised throughout the agricultural industry due to the added simplicity of the chain driven approach.

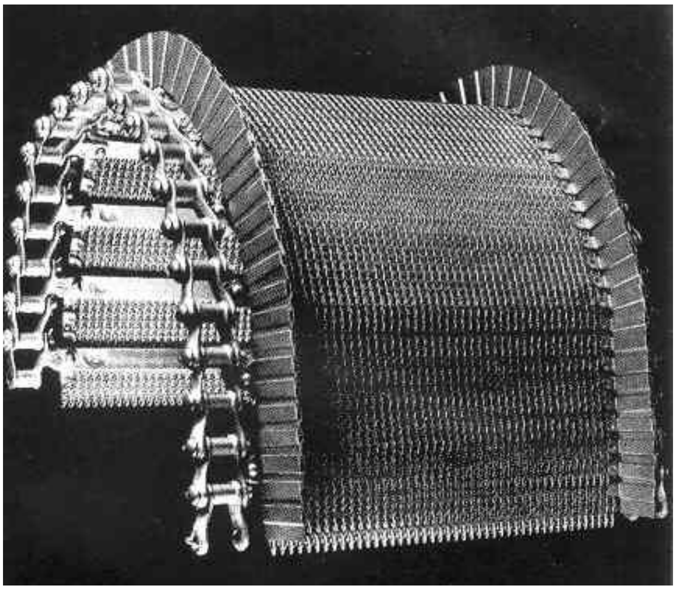


Figure 3.8 - Chain Weave Conveyor (Source: http://www.meshbelt.com/files/chain462a12.jpg)

This approach is less applicable to a variety of applications due to the restriction of movement from the chain weave however it poses to be quite effective in moving grain or seed in an axial direction. The chain driven approach proves to be more accurate as there is a reduction in slipping between the drive and the belt. As shown in the figure, the chain is attached to the base of the belt unlike the belt conveyors that utilises tension to create the friction to drive the belt. This approach can be seen in some found devices that are currently being used for feeding purposes as this accuracy can help the producer feed out at a specific rate.

The utilisation of conveyor belts on a smaller scale in the automated WCS feeder can very well be a viable design option due to the ease of creation and implementation into a small scale feeder. Also due to their simplicity and accuracy of control can prove to be very useful in the feed rationing. Use of these devices should be considered highly in the final conceptual design.

3.5.3 Chain Bed

Chain beds are used extensively in the cotton handling industry, they consist of chains that have small teeth like metal plates that bites into the cotton and move it along the belt. An example from (Deere 2013a) is shown in Figure 3.9 and can be seen moving a compacted cotton module.

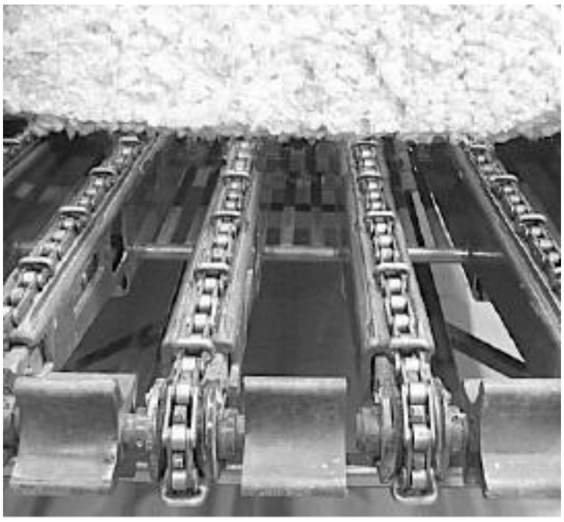


Figure 3.9 - Cotton Chain Bed (Source: http://www.deere.com/en_US/docs/agriculture/cotton_harvesting/cotton_modules/cotton_module_staging_instructions_truck_requirements.pdf)

Cotton seed on the other hand lacks the amount of lint around the seed making the chain bed not as appropriate as other means due to the nature of the bed. Since these chain beds are designed to move compacted amounts of cotton, the cotton seed would simply fall in between the chains. This would create a problem with efficiency and makes this option not viable in the automated moving of WCS.

3.5.4 Automated Bucketing System

The use of an automated bucketing system is quite a viable approach for this project as force is used to scoop out the product rather than relying on the flow of the product. This concept has been utilised by a variety of companies and applications. Some examples include the Bucket wheel excavator used in the mining industry. An example of such a device can be seen below in Figure 3.10.

Figure 3.10 - Bucket Wheel Excavator (Source: http://img.directindustry.com/images_di/photo-g/bucket-wheel-excavators-58589-4549569.jpg)

Other examples include the use of an automated water bucket system where, like the Bucket wheel, the device rotates in a circular or oval shape picking up the product and transporting it along an axis. When the device reaches its maximum the bucket empties itself before returning to the bottom of the cycle. The concept behind both of these applications is very applicable to the transportation of WCS along a particular axis.

Due to the simplicity of this automated bucketing system, modifications or creation of a new system that achieves the same handling technique would be easy to complete in tight time constraints. Since WCS is a light product the design and building of such a system would not require an extensive design that needs to be able to withstand a variety of forces like the mining device in Figure 3.10.

As previously discovered the current methods of handling WCS include the use of a bucket or manual shovel. This was the most utilised method of handling WCS currently. This bucketing method could however become automated if implemented on a rotating system like the method discussed. If the proportion, or bucket size, and the spacing between each bucket on the mounting wheel was carefully considered and analysed then an appropriate solution to the problem at hand may be reached. This should be highly considered in the design stage of the automated feeding device as this method is relatively simple to manufacture causing costs to be lower than other methods discussed. Also a variety of modification parameters including bucket size and how many are included on the mounting wheel is a possible consideration.

Also to be considered in this approach is whether the mounting wheel is fixed like in Figure 3.10 or rather an elliptical shape that is not solid but the buckets are mounted on a conveyor type system. The availability for producers to modify such a system creates the option for multipurpose applications on their property as this system would also meet the requirements of handling other grains.

3.5.5 Gravity Fed

This topic pays particular attention to the grain feeders that have been discussed previously. These devices make use of gravity and are designed for the seed to fall through cleverly designed grates or slots. The use of this technique in an automated device will happen naturally as the WCS will feed into the appropriate moving technique from the storage bin. Unlike feeders, this phenomenon will be utilised by the design to create a flow from the WCS.

As previously discovered WCS does not flow effectively due to its physical nature and proves difficult for producers to handle in this manner hence the manual labour approach. However after consulting various research it was discovered that there are possibilities to create WCS into a product that can in fact flow effectively. This product is called 'Easiflo', and is beginning to become more utilised in the farming industry as this product can simply be moved by traditional grain handling equipment. A fact sheet on this product can be found in Appendix C for more detailed information but utilisation of such a product may just be viable to drought affected producers for ease of handling. This product is simply a starch coating over the whole cottonseed which smooths out the product and reduces the 'fuzzy' Velcro like nature (Incorporated 2001). This product does not change any of the nutritional properties and boasts that it can benefit the density of the product creating the advantage of more seed per cubic meter. In fact in one cubic meter of standard WCS there is approximately 242 grams whereas Easiflo there is 311 grams per cubic meter meaning producers can store more products in a smaller storage space. This benefits producers simply because the amount of feed they can source to begin with during the drought season is greater creating a longer lasting supply.

By coating WCS we can find that by reducing the lint around the seed into a less 'fuzzy' state, the problem of flow becomes less like WCS and more like a traditional grain. This approach is very effective in answering the problem of handling difficulties and can potentially be utilised in this project as a design option. Pricing for such a product coating is subject to change with a variety of different factors. Due to the nature of the substance being made up of corn starch and a process of heating. This means that the cost per tonne can vary with the price of corn as well as the price of fuel to power the heating process. The process of creating this coating involves adding about 2% gelatinized corn starch to the seed. One short tonne of cottonseed takes about 18 kg (kilograms) of starch - to gelatinize 18 kg of starch it must be added to 181 kg or approximately 181 litres of water and heated to roughly 83 ^{0}C. The gel is then added to the seed and sent through a dryer to dry off the 181 kg of water. It was discovered by (Wedegaertner 2014) that it roughly works out to cost $10.00 USD worth of natural gas and corn starch to get the job done however to cover processing and handling costs the product sells, right now, for $50.00 USD per tonne. This as of 9th May 2014 amounts to $52.20 AUD per tonne. When we were actively building processing plants we figured it took about $10.00 USD worth of natural gas and starch to get the job done.

To conclude the findings for a gravity fed system, the phenomenon will be utilised in the final design but cannot be the only force present due to the nature of WCS and the device it is to be carried in. To get the WCS from the storage bin to the livestock trough or ground there needs to be another driving force present to effectively make this happen and these possibilities are covered in this chapter and will all be weighted appropriately in the final design concept against a variety of criteria that will be created from the problem outline.

3.5.6 Pneumatic and Hydraulic System

Another possible approach to transporting WCS is by utilising a pneumatic or hydraulic system. This could include the use of hydraulic or pneumatic devices that operate another part of the system to transport the WCS out into the trough or onto the ground. As previously discussed the use of a automated bucketing system may alternately be operated by hydraulic or pneumatic arms. Of course by implementing such a system into the design, costs will begin to rise since there will have to be an external driving force applied to operate the system. For example in a pneumatic system there needs to be a compressed air supply to feed the system for operation. Likewise hydraulic circuits need the additional reservoir and pump for consistent operation. Figure 3.11 is a simple hydraulic circuit to briefly depict the simple set up of a hydraulic system.

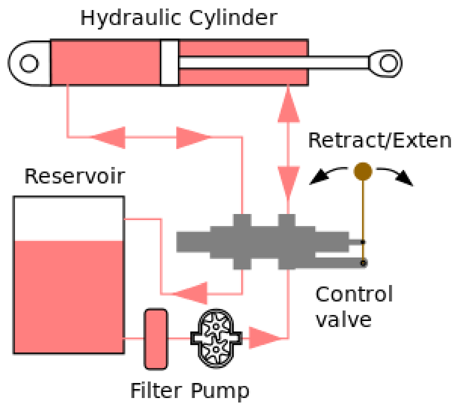


Figure 3.11 - Hydraulic Circuit (Source: http://upload.wikimedia.org/wikipedia/commons/thumb/4/4a/Hydraulic_circuit_directional_control.svg/301px-Hydraulic_circuit_directional_control.svg.png)

These devices can be remotely operated or set to operate automatically on timed control valves or even sensors can be used to operate the ram. In the scope of this project the main use for hydraulic or pneumatic rams would be to operate a simple bucket device that is filled and then discharged out a exit chute onto the ground or into the feeder. The benefits of using these systems is that the operator has an option of fully automated or triggered. With the addition of this feature, the producer can choose when they want to discharge a specific portion. The disadvantage to this method is that the feed cannot flow out in a continuous motion since the rams are operating in a linear fashion they are restricted to linear bucket type operation which may not be appropriate to this project and need to weighted effectively. Another disadvantage to implying such a complex system is the added costs in maintenance and upkeep. These systems have the possibility of failing much higher than a simple mechanical system. The main scope of this project is to limit the system to one main power source; the additional systems like pneumatic and hydraulic bring in the need for addition external features which is not appropriate for this project. These are just some simple observations noticed before a critical analysis is undertaken in such systems and the application they have to this project.

3.6 Conclusion

After consulting extensive resources on the variety of feeding methods currently utilised by the cattle industry there was a variety of different methods consulted. Each method had its advantages and disadvantages, some even proved to be not applicable at all to the problem at hand. However by consulting the variety of feeding methods currently used, there were four major groups that will be critically analysed in the final design process, these were:

1. Screw Conveyor
2. Conveyor Belt
3. Automated Bucketing
4. Chain Bed

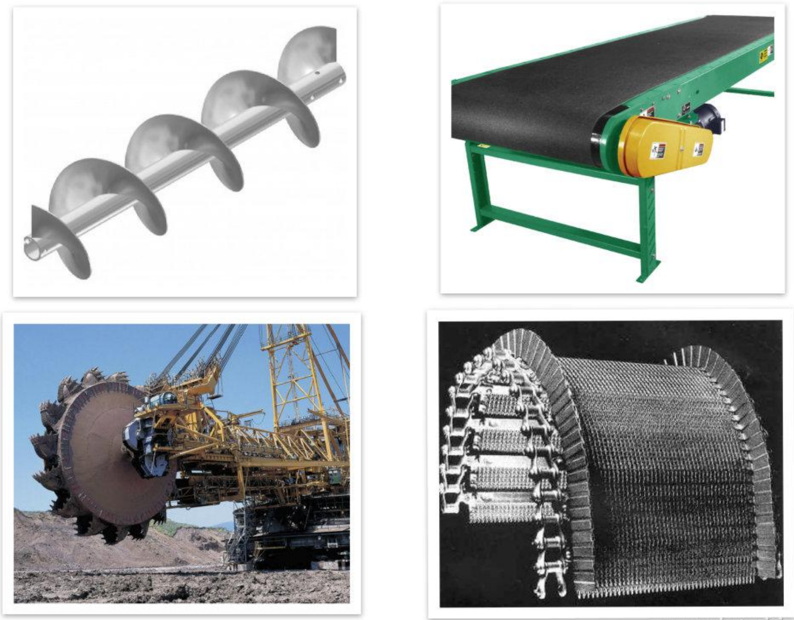
These major design systems show the possibility of being utilised in the final design for automatically feeding out WCS to livestock. Through the methods of selection criterion defined by the problem as well as critical analysis of the application these methods have in the final prototype, an appropriate method will be selected. The advantages and disadvantages of each approach can be seen in Table 1 below.

Table 1 - Method Comparison

Method	Advantages	Disadvantages
Screw Conveyor	• Cheap to manufacture • Move product at a fast rate • Can move product up an incline • Easy to source	• WCS does not flow into cavities
Conveyor Belt	• Easy to manufacture • Easy to source custom designs for belts • Effectively move WCS from the	• Expensive

	storage bin • Viable in small designs • 12V operated	
Automated Bucketing	• Simplistic Operation • General concept will work effectively in achieving the goal	• Complex to build and manufacture • Time consuming to build • Costly to build • Needs excessive space to operate.
Chain Bed	• Effectively move WCS • Allows for modifications	• Complex to create • Expensive • Gaps between chains will cause product to be lost

4 Critical Analysis of Existing Systems



Through the consultation of a variety of resources which discussed the many methods of feeding livestock there has been four major groups that need to be critically analysed with each other. These were:

1. Screw Conveyor
2. Conveyor Belt
3. Automated Bucketing System
4. Chain Bed

This process will extensively look into each advantage and disadvantage of each method taking careful note of the project limits and guidelines previously discussed. Each method will be compared rigorously against each other which should display the applicability of each method in this design project. This process will utilise previous research of each method in this particular application as well as some simple testing of each process with WCS. Before this analysis can happen there needs to be a selection made of the major criteria that is most important for this project as well as an appropriate method of confirming the research by a final selection method. This could be in the form of a decision matrix or similar selection process.

4.1 Initial Design Criteria

Due to the nature of this project there are a variety of crucial design criteria that need to be considered when finding a possible solution to the problem at hand. Some initial criteria that have been previously discovered from the problem description are:

1. Cost effective
2. Must be Automated and operated by single operator
3. Size - Can be mounted on a Ute tray back or trailer
4. Effectively off load white cottonseed feed

These four major criteria are the basic outline of the problem however there are potentially more criteria that need to be considered in this problem. These include:

1. **Mass** - Due to the product being mounted on a tray back or trailer the device must meet the limits of an average farm vehicle carrying capacity. Since one of these methods will be implemented into an existing storage bin, mass will need to be minimal. For this analysis the stock standard Toyota Landcruiser Utility will be used for a reference.
2. **Ease of Manufacture and Reproducibility** - Due to the nature of the device the manufacturing needs to be easily achieved so that costs remain at a minimum. The device also needs to be reproducible quickly for quick manufacturing and dispatch.
3. **Availability** - Can the materials and power devices be easily sourced for implementation into the system.
4. **Reliability and Durability** - Are the components and materials used to create the system as a whole reliable enough to maintain and meet the requirements of the machine.
5. **Maintenance** - Can the machine be easily maintained and serviced by the single user or do professionals need to be consulted. In particular this project has the sole purpose of reducing the operator numbers to one. This means that maintenance should be able to be completed by a single person.
6. **Implementation of Feed into Storage Bin** - Loading the WCS into the storage bin should be easy to complete with a bucket tractor or similar devices. This means the mouth should be large enough to handle the dumping of the standard bucket which is approximately 2.4 m in length (Deere 2013b).

7. **Ease of Operation** - Due to the nature of the project, the device should be completely automated except for initial starting. This initial starting should be as simple as pressing a button or engaging a gear. This conclusion is yet to be reached but should take into account this parameter.
8. **Easy method of attachment and removal** - The device should be easy to set up on the appropriate vehicle and easily removed once feeding has been completed. This should be considered highly as there are a multitude of methods to fasten the device to the tray of the vehicle. Does the tray need to be modified at all by the addition of mounting bolts or can the device successfully be secured by the use of straps and ties? This should be considered in the design criteria as the design is improved.
9. **Powering the system** - It is important to consider the powering of the system and whether this can be achieved from the vehicle or whether other systems need to be included in the design to meet the demands of the overall system. If the torque required by the device exceeds the amount that can be generated from a 12 Volt electric motor then maybe a petrol powered motor will need to be considered.
10. **Aesthetically pleasing** - The overall design should be sleek and appeal to the producer that is considering the purchase of the system. A good choice of color scheme is important and should be considered in the final design for the purpose of marketing and promotion. Practical colors will need to outweigh vibrant colors simply because the device will be exposed to a harsh environment. This will be an important factor when promotional material is created and a sleek design will need to grab producer's attention.
11. **Available Worldwide -** The system needs to be available not only in Australia but also throughout the world. The system will ultimately need to be able to make money for the buying company. If the design in the end cannot be sourced worldwide will there be enough demand in Australia alone? This needs to be considered when deciding on the materials and manufacturing processes.

These are secondary design criteria that should be highly considered in the final design. Each point should be investigated thoroughly to find the most appropriate system answer to best fit the requirements of the final design which are yet to be discussed. These design criteria are important for the overall design to specifically answer the demands of the project and create a system that can effectively feed WCS out to livestock in an automated fashion. The criteria listed each have importance to finding an answer to the project and produce a design that can be created.

4.2 Requirements of Final Design

The final conceptual design that is to be created in the future is to be of a professional grade and needs to meet some requirements. These requirements have been previously discussed throughout the beginning literature. However before a critical analysis of the four chosen systems is undertaken, these requirements should be summarized and noted for quick reference before comparing these systems to the requirements of the final design. It is important for the project to keep these requirements in crucial consideration when creating the concepts and prototype. Each requirement is different from the design criteria since these are permanent and have only one limit where as design criteria are given slack in different areas.

The first of the final design requirements is that the structure should be manufactured to a high standard and be constructed with heavy duty components in mind. This requirement is so that the systems can withstand the rough territory of the Australian farming industry. This is a crucial requirement because the machine with need to withstand exposure to these environments all year round. Since the costing is yet to be sourced, of course a heavy duty and long lasting system would be most appropriate since the producers would want to make the purchase only once. This requirement is to be considered highly when comparing against existing systems.

Another requirement of the final design is to meet size limitations. The most common vehicle that is currently utilised in the farming industry is the Toyota LandCruiser 75 Series (Wooldridge 2014). The approximate dimensions of a typical tray is 2.3 x 1.9 meters (Sourced from (Moore 2014)).These dimension are the limitations of the tray back final design. This will be the first motive of the project, to create a system that can be mounted inside the tray back of a utility. This requirement is also extremely important for these existing systems to meet. The existing systems need to be able to operate still at a high level even with the smaller size limits.

Additionally another requirement of the final design is to be able to be powered from a standard 12V DC car battery. The system needs to either be attached to the trailer power supply or hard wired into the vehicle. With this in mind the goal is to keep disconnection easy and quick so that the producer can dismount and disconnect the machine with ease. It is important for the final design to be mindful of the power that is present and whether addition measures need to be taken to meet the feeding requirements or the torque needed to drive the system.

Another crucial requirement of the final design is to keep costs low to remain affordable for drought affected producers. With the project aiming to keep costs as low as possible the overall implementation of a system that keeps this goal in focus is key to successfully finding an appropriate answer for the project. Ultimately the cost will be one of the first deciding factors that deter possible customers of the system, if the price is too high, buyers will run and sales will be lost. This is extremely key for the design so that it can be feasible and practical to the industry.

The final requirement of the final design is to adequately handle WCS in its raw and damp forms. The main problem with WCS, as previously discussed, is the physical nature of the product once it is exposed to different elements. The final design needs to overcome the toughness of handling no matter the form of the feed. The key here is to be able to separate the seeds from each other and create either a flow of feed or monitored portions. This is the most important requirement of the design and should be the key in choosing a final solution.

These crucial design requirements are to be considered first before any other design criteria are compared. The requirements of the final design are the ultimate goals of the project and will be the driving force behind finding a solution and proposing a prototype.

4.3 Comparing Existing Systems to Requirements of Final Design

From the given parameters and design criteria that have previously been listed, the four chosen systems for analysis will be compared with each other against the final design requirements. Once each design has been critically compared to the final design requirements, a decision will be made on which system is most appropriate for the conceptual design of an automated WCS feeder. The requirements of the final design as previously discussed are:

1. High structural durability and heavy duty components
2. Maximum and Minimum size limits
3. Perform from 12 Volts

4. Low Cost
5. Can adequately handle WCS in its raw and damp form

These five requirements are to each be discussed with regards to each of the considered design systems. The five requirements initially will cause a leader to form and then through the use of a selection matrix the ultimate candidate for the prototype will be discovered.

4.3.1 High structural durability and heavy duty components

The first on the five requirements given to the system is a high structural integrity and heavy duty build. It is important in this application to install a system that is durable enough for the application that it will be exposed to. The first of the systems is the screw conveyor which withholds its structural integrity throughout some extensive environments due to its application in the augering industry already. It has been used for offloading grain for years and seems to be the most utilised in the farming industry apart from the conveyor belt system which will be covered later. The screw conveyor is created from steel of a variety of strengths changing with the size needed. In the application at hand only a small screw conveyor is needed making the ability to create a heavy duty screw conveyor very affordable and quite simple to do, making this a viable approach in this requirement.

The conveyor belt on the other hand due to its rubber belt approach is still of high quality however exposure to the elements extensively could cause damage to the integrity of the belt. This approach has been utilised however in the farming industry as of late due to the high quality of belt crafting materials. Even though the material may be exposed to wear, no matter the material there is always going to be some wear due to friction or, in the case of conveyor belts, weathering. The advantage this approach has over screw conveyors is that the wear between two metal surfaces is eliminated. The wear may cause problems with the durability of the design if not considered highly. The important fact of the conveyor belt is that the system is a lot more controlled, quieter and reduces wear on external components. Because these belts are now created with such high standards, this approach will be adequate to meet the heavy duty requirements.

Likewise the automated bucketing system can be created to become quite the heavy duty system. Due to the nature of the system a heavy duty structure is needed to build a small scale model of the pictured design. Like the screw conveyor the buckets and webbing can be built from a high grade steel. Due to the nature of the structure of this design it adequately meets the heavy duty requirement of this project. Even though this design can be built to meet heavy duty requirements the size of the wheel or means of holding the buckets needs to be considered highly as creating this design to operate inside or outside the storage container.

Finally the chain bed even though it is created from a system of chain links of some nature, it would have to be the flimsiest of the four designs considered for the system. This is due to a structure built from a series of sub-systems. This will cause problems during manufacturing due to the complex nature and will also create problems when fitting into the final system. Keeping the chain bed tight during operation will prove to be another addition to the maintenance of the system. If the product is not made from high durability materials then the chain will stretch over time which will in turn affect the integrity of the system. This said the system made from a chain bed could be useful in the WCS application as the material will need to be aggressively pulled to separate it from each other, and a chain bed will meet these criteria well. If the chain is created from high grade materials it may be able to effectively hold its structural integrity.

4.3.2 Maximum and minimum size limits

As mentioned previously the limits of a typical LandCruiser tray are 2.3 x 1.9 meters. It is important for this project to consider these dimensions as a mid range limit since the tray sizes can change minimally. Typically the length of the tray is what changes the most however the width remains constant with the typical LandCruiser cab width. The conveyor belt systems and the screw conveyor adequately can be built for the width and length width with little to no hassle compared to the design and consideration of the automated bucketing system. The benefit of the three conveyor systems is that they all currently hold a place in existing systems of small lengths like 1.9 - 2.3 meters. These systems typically are used for the transport of smaller light weight objects that need to be systematically taken from one place to another. One particular leader in the precision conveyor belt industry is (Dorner 2014) who create a variety of conveyor systems that adequately fit the limits of this project. Shown below in Figure 4.1 is an example of a small scale conveyor system that is being manufactured by Dorner.

Figure 4.1 - Small Scale Conveyor Belt System (Source: (Corp. 2013))

Likewise there are a variety of small scale screw conveyors that are being utilised in a variety of applications throughout production today. Shown in Figure 4.2 is an example of such a system. A small scale design like these cause more design work to take place to prove whether systems this small can adequately meet the requirement of the system as a whole.

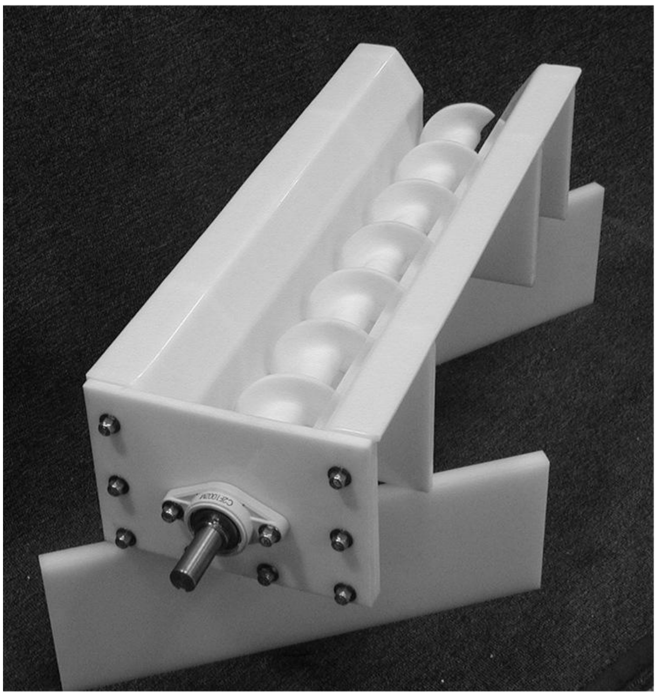


Figure 4.2 - Small Scale Screw Conveyor (Source: http://millardmfg.com/products/Pictures/135569390.jpg)

Through research the application of small scale bucketing system would require more design and sourcing as the parts are not as available as the conveyor approach. Due to the need of a complete system being created rather than sourced from existing companies.

These discoveries motivate the project to consider more highly the three conveyor approaches in regards to the system being able to remain within the given size constraints.

4.3.3 Perform from 12 Volts

All of the four systems can adequately be driven by the use of 12 volt DC motors. They can either be run directly from a chain and gear system that is connected to the main motor by the use an axle. Other approaches include the use of belts however the system is required to produce high torque on the belt which will cause slipping to occur. With this in mind the most appropriate way to transfer the torque from the electric motor into the system is the use of a chain drive. This approach is also easy to maintain and is relatively cost effective for the producer. By keeping the electric motor outside the storage bin the system will be easily maintained and monitored. This creates an added benefit since the producer can monitor whether the system is operating properly from the driver's seat of the utility. Due to the benefit of 12 volt electric motors and gear reducers, the required torque by the system can be met effectively and no additional systems need to be included in the final design (e.g. use of an additional motor for the system alone). The systems will also benefit from this requirement as the producers can wire it into their existing vehicle and no additional step is needed. With the system remaining 12 volt the producer can also utilise the trailer power outlet that is present on nearly all utilities. This means that the system can be mounted on a trailer as well if the producer needs the utility tray for other purposes. Since all systems can effectively incorporate a 12 volt motor they all meet the requirement well due to them all having the possibility of incorporating a chain, gear and axle system or something following the same basic concept.

4.3.4 Low Cost

At this stage in the project because final dimensions are yet to be confirmed the costing comparison will be undertaken with some estimated dimensions. This is just to use as a guide for the choice on which design best fits the costing and whether it is appropriate for this analysis. For the sake of this analysis I have chosen a maximum length of 1.5 meters for the flight length of the conveyors. This was chosen due to the fact that the utility tray is roughly 1.9 meters wide. Allowing for the chute run on one end of the feeder, 1.5 meters is quite appropriate for this initial analysis of costing.

The first system is the screw conveyor which is quite readily available in the agricultural industry and quite effective to manufacture at these lengths. After sourcing as many costing options as possible in the time frame given, it was discovered that the screw conveyor option would cost an overall $2500.00 AUD for the creation and manufacture of the device. This cost was produced after initial dimensions of 20 millimetres in diameter and 1900 millimetres in length were given. Once an initial design for the conveyor is completed the design cost will be lowered and mass production of the screw conveyor could be completed.

There were multiple companies contacted throughout the research process but only a couple returned with costing for the screw conveyor. Once a final prototype is ready and viable for design, companies will be more inclined to the concept. Due to the nature of this research paper, companies were very limited in their help and so further analysis of the costing would need to be completed to give a 100% accurate result. The results given however prove to give a good overall limit on the device creation.

Unlike the chain bed approach to be discussed, the rubber belt conveyor system can be a lot cheaper due to the much more utilised approach of rubber belts. Because rubber belts can be produced in mass it is quite easy to create such a small scale belt. These smaller scale belts can be utilised in a conveyor belt system which ranges from $3000.00 to $4000.00 AUD for the scale that would need to be used in this application. These prices again were taken by a limited number of sources due to the lack of commitment the companies wanted to make towards the initial concept. These costs will be able to give a comparison quite effectively throughout the final analysis.

Finally the automated bucketing system comes with of course quite the large increase in costing since you need a system of the buckets which are attached to the main circular structure. Due to the fact that most of these parts are created from steel the cost of building the wheel increases dramatically with the increase of manufacturing and the increase in labour. Ultimately this design exceeds the budget above and beyond any of the previous designs discussed. Due to the high increase in costing due to complexity this design, the score is dramatically lower than the competitors.

This cost analysis discussion displays the importance of discussing the costs involved in the project and gives a solid basis for the decision matrix. This analysis effectively has shown the most cost effective approach to the problem and the scores can be found in Table 2.

4.3.5 Can adequately handle WCS in its raw form

The most important factor that will need to be taken into consideration is the ability for the system to handle WCS in its raw or damp form. If the system does not incorporate the ability to overcome the difficult physical properties of the product then that system cannot be considered further. Some of the most important parameters to consider with this project is that WCS has a 'Velcro' like binding to itself meaning the system will have to separate the product enough so that a portion can be met. With this in mind the system that can be utilised in this project will need the ability to be modified enough to still meet standards but create something to achieve the goal of transporting WCS to a feed chute.

From the four systems analysed, there are three main design concepts behind them. Belt, screw and bucketing systems are what these design utilize. At this point in the analysis it is important to consider the different modifications each system can incorporate to try and handle WCS in its raw form. The most important thing to remember in this stage is that WCS has a binding nature so all designs need to incorporate some sort of means of separating the feed from itself. By modifying an existing design the cost will increase but since costing has been considered already the modifications will be consulted once a design has been chosen.

The screw conveyor is the most inconvenient design to modify due to its tight constraints within the system. However one way this could be modified is by adding a tooth like blade to grip and rip the feed away from the storage bin. This process is obviously quite aggressive and would need to be tested on its effect on the product as a whole. An example of the tooth attachment concept is shown below in Figure 4.3.

Figure 4.3 - Example Tooth Concept (Source: http://www.lane.us.com/images/woodfd-2.jpg)

This design is to merely give a visual aid on the thoughts behind what could be done to a screw conveyor to try and solve the raw form handling problems.

The conveyor belt systems prove to have the most room for improvement due to the work platform available. The production of the conveyor belt stage can be used to create new belt exterior faces. These faces can have teeth like grooves or attachments that will be used for the removal of the feed from the feed bin. It is important for the design to adequately handle the force required to overcome the resistance the WCS has before separation. Below in Figure 4.4 we can see the variety of different moulding options for the conveyor belt system.

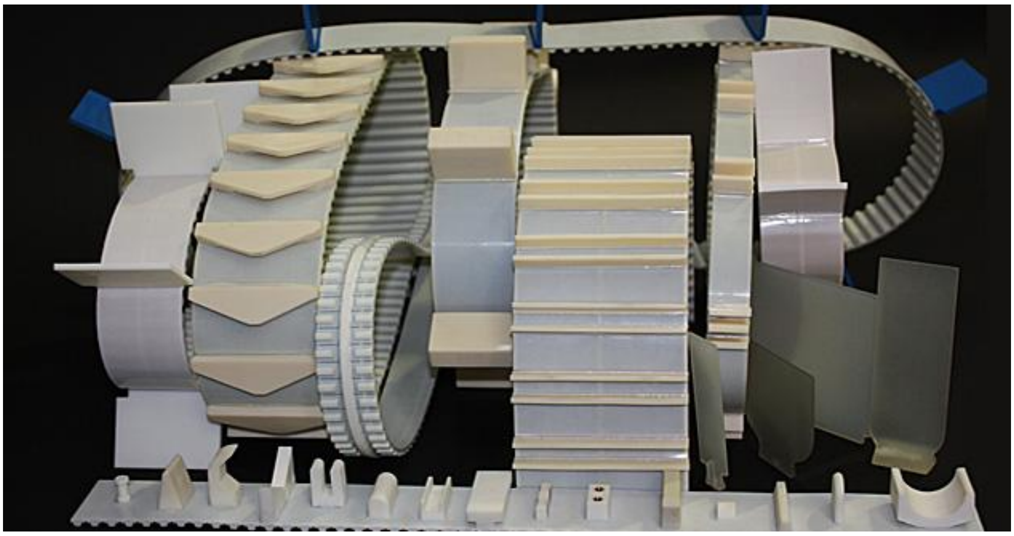


Figure 4.4 - Conveyor Belt Modification Examples (Source: http://www.morinex.com/images/jpgs/4945lr.jpg)

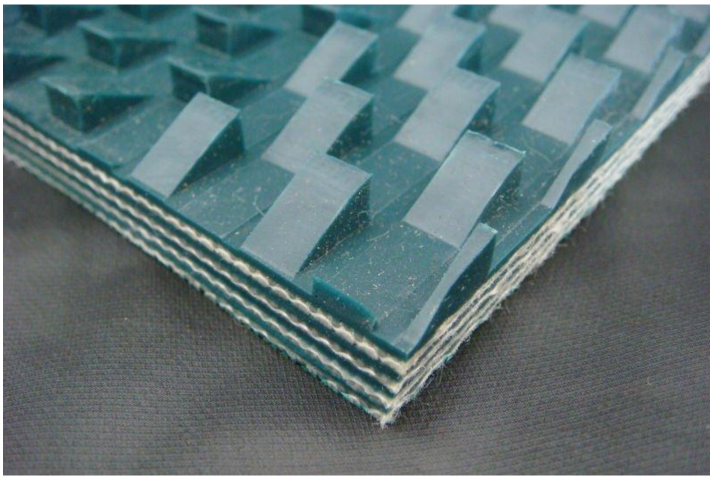


Figure 4.5 - Conveyor Belt Teeth (Source: http://i00.i.aliimg.com/img/pb/709/248/519/519248709_067.JPG)

Shown above in Figure 4.5 is an example of a more appropriate approach at this stage of the concept due to the aggressive tooth like features. The material is slippery enough for the WCS to not bind itself to the belt but once the product has been separated should be free to fall into the chute at the end of the belt. This will benefit the project as a solution may be possible with this approach.

This is of course not the only modification options, as a lot of different applications require more aggressive or tougher approaches. This is where some companies create the belts and attach other blades onto the belts by means of bolts, rivets or by creating grooves in the actual belt design to house different attachments like shown in Figure 4.6.

Figure 4.6 - Conveyor Insert Example (Source: http://www.martin-eng.com/products/media/catalog/product/cache/1/image/800x800/9df78eab33525d08d6e5fb8d27136e95/b/c/bc07003h.jpg)

These inserts can be designed to withstand a variety of forces and could prove to become very useful in the final concept.

Finally the bucketing system proves to be open for design modifications, however the only additional design changes can be undertaken on the blade of the bucket. Like the conveyor systems, the buckets can be exposed to a variety of different face treatments and attachments to meet the requirement of the job at hand. Of the four systems, the automated bucketing system would score the poorest in availability for design evolution. However the design proves to be able to handle the WCS as a raw product as this method is the closest to bucketing or shovelling as the process mimics the action. Like the conveyor processes the bucket can be modified on the contact face. The main options seen is the tooth or the straight blade approach. An example of each can be found in the figures below.

LEFT Figure 4.7 - Tooth Bucket (Source: http://imavex.vo.llnwd.net/o18/clients/runyonrental/images/4100.jpg)

RIGHT Figure 4.8 - Straight Bucket (Source: http://www.attachmentscjj.com/images/dirt-bucket.jpg)

These buckets obviously need to be generated at a further cost to the producer as they need to be attached onto the main structure after production. The design would meet the requirement of handling the WCS in its raw form however poses many questionable disadvantages to the solution of the project.

From this analysis of the ability each design handles WCS as a raw product, it can be seen that each design on paper can adequately be modified to handle WCS in its raw form.

4.4 Selection of Usable System

The choice has been made to use a decision matrix to better weigh each design against each other and find out which one best fits all the final requirements and criteria. By giving each system a score out of ten and totalling the scores, the four designs will be adequately rated and an order of best fit will be formed. This order will then be used to base the final design around. The matrix used is shown below in Table 2.

Table 2 - Design Decision Matrix

CRITERIA	SYSTEM ANALYSED			
	Screw Conveyor	Conveyor Belt	Automated Bucketing System	Chain Bed
Size	9	10	7	9
Mass	8	10	7	9
Cost	10	7	7	8
Off Loading Capability	8	10	9	8
Manufacturing/Reproducing	9	10	7	9
Availability	10	9	8	9
Reliability and Durability	8	9	7	8
Maintenance	10	9	7	8
Ease of Operation	10	10	10	10
Installation/Removal	9	8	9	7
Power Requirement Met	10	10	10	10
Aesthetically Pleasing	8	9	7	9
Loading the Storage Bin	10	10	10	10
TOTAL SCORE	**119**	**121**	**105**	**114**

4.5 Final Critical Comments

Throughout the extensive analysis of the four considered systems, the decision for the conveyor belt system to be utilised in the initial final concept of the automated WCS feeder. Through the research into the systems and comparing them effectively with one another an accurate decision was drafted. Initially the screw auger seemed to be an adequate and cost effective approach to the answer however this system proves to lack in consistent product contact area. Once the initial layer of WCS has been taken away, if the product still remains bound together, an even flow of feed is hard to achieve. This leads to the discovery that conveyor belts have consistent and even contact with the product and do not require the product to fall but rather be torn and dragged away. In turn this process will pull the upper layer down as well creating a chain effect on the product.

The automated bucketing wheel was just an inapplicable approach to solving this project due to the required space for operation and the inability for the design to meet low cost requirements. Due to these factors and the score of the design overall makes this approach inapplicable in the design.

The decision that the conveyor belt approach is most appropriate prompts the project to design a system that can effectively test these findings. This project aims to create a prototype design that is ready for future construction. This build will then be able to be tested in the particular application for further results to be discussed. However with these statements comes confidence that through the analysis of the final system and small scale testing on the product the project will draw some effective conclusions. These conclusions will be utilised to prove the applicability of this system in the practical application and provide a solution to the given problem.

Now that these conclusions have been given it is important for the design sketches to be completed and final material selections generated so that the final stages of the design can be created. The following chapters plan to discuss all the design parameters that need to be considered and incorporate them into a final prototype.

5 Preliminary Design Considerations

It is extremely important for the Automated WCS Feeder to consider a variety of factors before coming to a possible conclusion. These factors are the initial considerations that need to be put forward before any prototype is completed. This will give the design guidelines on what to follow and the most appropriate answers for that particular factor. A summary of previous discussions will be undertaken to clearly state the existing systems and then discuss the new design considerations this project is aiming to follow. Completion of this discussion will give the project scope on what is important and what will benefit the project overall.

5.1 Summary of Existing Systems and reasons why they are currently not being used

It is important to provide a summary of the systems that were discovered during the research so that the preliminary design takes into consideration the discovered systems and to provide a precise introduction into where the design philosophy originated from.

Figure 5.1 - V Mix Plus (Source: (Lengerich 2014))

Shown in Figure 5.1 is the V-Mix feeder utilised by varies producers in the United States. This product was inappropriate due to the nature of system. This particular machine mixed the product into a even feed and then fed out through a exit chute depicted above. Due to the nature of WCS, keeping the product moving would be difficult to maintain. Since the exit chute is created from a conveyor system, elements from this design could be modified to achieve effective WCS handling but this system is ultimately not appropriate for the product at this stage and hence why it is not being used for this purpose.

Figure 5.2 - Bar6 Feed Dispenser (Source: http://bar6.net/feed-dispensers/)

Figure 5.2 displays the simple feed dispenser design which proves to be an appropriate for storage means but ultimately has no internal or external system that proves to be of any use for WCS handling. However the lid design could be quite useful as it folds away rather than lifting off or swinging up. When considering the loading of the device on the rear of a utility, it is extremely important for the device to be able to be loaded by use of a bucket tractor. When loading is occurring it is important to contain any spillage of the product. Also protection of the utility cab is important for the system to consider. The use of a lid that folds up to restrict the product from falling in between the utility cab and the system. Even though this device possesses no real use in the application being analysed, the system has some design ideas that should be considered in the development of the final concept. Of key importance is the design of the lid system and the discovery that the system should use a means of restricting the WCS from falling past the storage bin.

Figure 5.3 - Heavy Duty Cube Feeder (Source: http://tarterusa.com/tarter-products/heavy-duty-cube-feeder/)

The heavy duty cube feeder utilises the compacted cubes approach for dispersing feed to the livestock. This particular design does not incorporate the ability to handle WCS like the previous feed dispenser. The lack of interior and external systems make these feed dispensers inappropriate in this application without some modifications. This designs show lack in the automation department and need a rigorous overhaul to make them a viable option. By taking some aspects of each system a possible candidate may be created.

The trip hopper range feeders shown in the Figure 5.4 - Figure 5.6 inclusive, display appropriate design traits for the application in this very problem. Due to the nature of their builds and the ability for them to be utility and trailer mounted gives them very appropriate aspects for use in this project.

Figure 5.4 - Trip Hopper Feeder Trailer Model (Source: http://www.tsfeeders.com/graphics/tr_01.jpg)

These systems currently are being utilised only in the dry pellet and grain feed departments and no literature discovered proved that these systems were being used in the farming industry for the automated feeding of WCS. Many of the sub systems utilised in all of these designs display the ability to be tested in a automated WCS feeder conceptual prototype and should be rigorously tested.

In summary, all the discovered and discussed systems currently utilised in the automated feeding of WCS are extremely rare due to the problems with handling the product. Due to the fact that so many sub systems being used in each of these design prove to be possible candidates in the final design of an automated WCS feeder, prompts further analysis into an improved design based from the foundation created by these manufacturers.

Figure 5.5 - Trip Hopper Feeder Small Truck Model (Source: http://www.tsfeeders.com/graphics/jr_01.jpg)

Figure 5.6 - Trip Hopper Feeder Large Truck Model (Source: http://www.tsfeeders.com/graphics/pu_01.jpg)

5.2 Design Conditions

It is important for this project to define the conditions of the design. Keeping in mind these conditions of where the project has come from over the last few months and whether the project is going to meet the final requirements in the end of the process. It is important after all the recent discoveries to summarise again the main design conditions and the importance they stand within the project as a whole.

The project in the beginning set out to meet the following conditions of the original problem;

1. Create a fully automated feeder that can reduce the workload of the process to one producer.
2. The design must be able to be mounted onto the tray back of a common utility and be relatively simple to mount and demount by one person with the aid of a lifting device.
3. The cost must remain as low as possible since the project is aiming at drought effected livestock.
4. Easy to manufacture and readily available worldwide for purchase. In particular to this project Australia is the main customer in the initial stages.

These four conditions are the driving force behind the research and development of such a system to be utilised in the drought affected areas of Australia. It is most important for these conditions to remain firm throughout the final creation of the design concept and prototype models.

5.3 Key Overall Design Parameters

Like the design conditions it is extremely important for the project to meet the key overall design parameters. These parameters are created so that the design in the end meets all the demands of the project and can be used as accountability measures as the project finalises to keep the work on a defined track. There are five key design parameters that will be consulted in the final stages of design to keep the work accountable to the goal of the project. The importance of these parameters is paramount for the project to find a possible solution and produce relatively precise testing results. These key design parameters are listed below;

1. Overall Machine Size
2. Power Source
3. Desired Feeding Rate
4. Maintenance
5. Cost/Budget

Each of these design parameters will be briefly summarised to create an easy reference for the final analysis in the last stages of the project. The analysis of the concept with regards to each parameter is key to keeping on track and will be of highest importance as sketching and modelling begins.

5.3.1 Overall Machine Size

The initial design concept should be limited in its size due to the restriction of the LandCruiser Tray. This tray will be used in the conceptual stages as this is the stock standard size of most utility trays on the market. For the initial design the capacity that the machine storage container can hold is extremely important as we need a device that will effectively be able to handle enough product so that the producer can feed a relatively large herd. As previously discussed the typical medium sized herd is around 200 - 300 head of beef cattle. For the purpose of this analysis the medium sized herd seems appropriate and will accommodate for many producers in smaller scale operations that would be looking for a device to meet this need.

The medium sized herd discussed would require approximately 750 kg of WCS to feed the maximum quota for the day. This prompts the overall size of the device to be able to hold approximately 800 kg of product in the storage bin.

(Willcut, Herbert M, Mayfield, William D & Valco, Thomas D 1997) state that the average density of cotton seed is roughly 25 lb/ft^3 which converts to approximately 400 kg/m^3. With this conversion in mind a bin that could hold roughly 2.0 m^3 of WCS would effectively meet the task. An initial sketch of this design can be seen in Appendix D and boasts the ability to remain in the size limits of the LandCruiser tray. This sketch is an initial visual aid used for generation of the shell and more detail will be undertaken to generate the feeding and chute systems.

From this sketch the following dimension can be used for initial model generation;

Length - *1.9 m*

Width - *1.0 m*

Height - *1.2 m*

These are the general overall sizes for the concept design and will be used appropriately.

5.3.2 Power Sources

The application of this device in the field is extremely important for the project. This prompts the analysis of the power source needed for proper operation of the system. For the system as a whole to be completely operational in the remote outback of Australia it is important for the power source to be dependent on the vehicle. Having an additional power source for the system not only adds to the cost but also adds to the space needed within the limits of the tray. With this in mind the creation of a system that can operate through the utilisation of a high torque 12 volt electric motor will benefit the design as a whole. This is important for the design to take into account during the final conceptual stage. Having the final design fully powered by a 12 volt source will simplify many aspects of the system and yet again keep the costs of manufacturing lower than if the system was externally powered by a petrol or diesel engine.

With the advances of today's research into the electric motors, it is easy to source a motor that is 12 volt DC and can output a high degree of torque, sufficient enough to operate a small scale conveyor belt. During the final conceptual stages, the choice of an appropriate electric motor for the size of the conveyor will need to be given to implement into the final prototype but the most appropriate is a small scale motor with an appropriate gear reduction gearbox to drive the main axle.

For the analysis of this prototype, keeping the design to a 12 volt DC powered system will simplify the system enough for modification during future testing and proves to benefit the marketability of the device.

5.3.3 Desired Feeding Rate

As previously discussed it is most important for the device to automatically feed portions out to the livestock in a manner that is not constant but rather follows the current methods. Producers currently utilising a bucketing approach feed out the product in a manner that splits the herd into smaller groups so every animal gets a fair share of the feed. Of course this approach is not 100% accurate as some animals dominate the feed, however when the automated feeding system is used, small portions laid out over a long stretch will effectively separate the herd for consistent feeding.

The approach of portions prompts a timed release device that can build up a small amount of feed before dropping out the exit chute. This catch device will not have to be 100% accurate however if the trap can contain approximately 10 to 15 kg of WCS then each portion will be able to feed four to six cattle. This will initially cause the herd to separate effectively as portions are dropped into the field. Therefore the desired feeding rate for the system is to be able to drop 10 - 15 kg portions for the livestock. Initial testing on how fast the device can produce these portions will need to be undertaken for accurate readings on how the whole system needs to interact. The speed of the conveyor belt and the time needed to build up a portion size of 10 - 15 kg needs to analysed before final implementation. By using the chain and gear drive system, the reduction of speed is a simple task and will prove effective in the final testing of the project.

Ideally the system should only produce a portion every few meters to compensate for the cattle groups backing up to each other. Considering the length of two beasts and a significant distance between each of them, there should be at least six meters between each portion. Depending on the speed of the utility will also be a factor to consider on defining the desired feeding rate. By creating a variable speed on the conveyor the producer can overcome the variables and set the system to feed out the desired portion at the desired distance apart. This will then give the ability for the producer to make changes of feed rate on the fly by increasing the travelling speed of the vehicle.

In conclusion the desired rate of portion size is 10 - 15 kg and the distance apart can be varied by the speed the producer travels at and also the possible implementation of a variable speed on the conveyor system. This approach will need to be tested and poses to be a great asset to the system.

5.3.4 Maintenance

Due to the nature of the project and the requirements that the system be fully operational by a single operator, maintenance of the device needs to also be a single person job. The key parameter to be considered when approaching maintenance for this project in particular is the simplicity of the overall design. By creating a simple conveyor/auger system that leads to one end where a timed chute is in charge of dispersing the portions maintenance can be kept at a minimum. If the design remains as simple as needed then it will be easy for the system to be properly maintained by one operator. It is important for the system to be properly lubricated and the internal critical components are easy to access and replace. The use of both an auger or a conveyor causes both ends to have bearings and a single driving force. By the use of an external drive the only internal components would be the rollers of the conveyor belt or the end bearings of the auger flight. This creates an excellent system since the only components that could fail can only be replaced and no internal maintenance other than lubrication.

By containing the driving components to the exterior of the system the producer can simply monitor all the drive components and lubrication can be achieved easily. This benefits the producer greatly as maintenance can be monitored and problems can be easily discovered and fixed. Keeping these parameters in mind that the drive system is to be kept exterior to the system, the design will achieve a simplistic maintenance regime and be pleasing to all producers who purchase the product adding again to the marketability of the product.

5.3.5 Cost/Budget

The most crucial design parameter to meet is the budget of the project. Throughout the research into the area of feeding livestock it can be seen that the cost of these devices range drastically. However it can be seen that automated feeding systems similar to the system this project is trying to achieve are limited, but range around very similar price ranges. Depending on the storage size required changes the costing of each device. For the purpose of this initial development the size depicted earlier will give merit on the pricing.

Assuming the system for initial conceptual designs contains 800 kg of WCS, the device would approximately cost $4000.00 AUD. For the initial design parameters and giving an ultimate budget for the project, the system should not exceed a manufacturing cost of $8000.00 AUD. This limit will help the production of the system remain simple. This budget is an initial estimate to give an absolute value to remain below. It is important for the project to remain as far below this limit as possible but this ceiling value will give guidelines for the prototype and still proves marketable.

In conclusion the design should try to reach a prototype within $4000.00 - $8000.00 AUD. This budget should allow for many factors including modification and the automated system for feeding out the produce. The concept could be quite competitive in the agricultural market if this budget is met well and the device could prove very marketable in the agricultural industry.

5.4 Conclusion

All the design considerations covered have given the project of design an automated WCS feeder for livestock have been discussed appropriately displaying excellent parameters and guidelines for the final concept to follow. Throughout the final stages of design it is important to refer back to all the design parameters and guidelines given, these are listed in summarized form below.

Table 3 - Design Consideration Conclusions

Appropriate Initial Dimensions	1.9 m x 1.0 m x 1.2 m
Power Source	12 Volt DC Electric Motor
Feeding Rate	10 - 15 kg fed out approximately every 6 meters
Maintenance	Low maintenance by internal driving system and simplistic conveyor design
Cost	Budget between $2500.00 AUD and $8000.00 AUD

These important parameters are also complementary of the design conditions stated below;

1. Create a fully automated feeder that can reduce the workload of the process to one producer.
2. The design must be able to be mounted onto the tray back of a common utility and be relatively simple to mount and demount by one person with the aid of a lifting device.
3. The cost must remain as low as possible since the project is aiming at drought effected livestock.
4. Easy to manufacture and readily available worldwide for purchase. In particular to this project Australia is the main customer in the initial stages.

These parameters and conditions are key to the creation of an effective system to meet the final solution to the problem at hand. If all the factors are considered highly during the final stages of the system design then an effective machine will be created and can be utilised in the practical application.

6 Generation of Conceptual Design

Before final prototype creation can be undertaken, a conceptual design must be generated to govern the creation of a prototype for final testing. By discussion and investigation into a variety of aspects of the design, effective limitations can be created. It is most important at this stage of the design to give initial limitations so basic dimensions and models can be created. As the final modelling stages and costing will need to be undertaken before a prototype is created, it is most important to analyse the limitations of the concept and how the concept may be produced. These limitations will be used in conjunction with the design criteria and limits so that the final prototype concept meets all the requirements.

6.1 Conceptual Design Limitations

The conceptual design will need to have limitations alongside the various guidelines previously given. These design limitations will be more in detail and pay closer attention to the physical side of the design. It is important at this stage for the concept to cover the limits on the general assembly and operation of the machine in the real world application. These limitations will include materials used to build the device up to the operator instructions and mounting methods. Once limits are given on these specific topics it will become easier to define the scope and cost of the final design concept.

6.1.1 Materials

The storage bin and the exterior frame needs to be highly considered in the conceptual stages so that the right materials are sourced for costing and easily accessible. The storage bin being the bulk of the design will need to be created from a material that is heavy duty but can also be bent and rounded into a specific shape. Due to the bin needing to concave into the centre where the conveyor belt is, the bin material considerations will need to take this into account.

Through research into the current feeder bin designs, nearly 100% of them are crafted from steel. The benefits of sheet metal is that it can be bent easily and it is very durable compared to a variety of other materials. This material is also widely available in a multitude of sizes, as seen in Appendix H, and at a reasonable price for this project. Due to the nature of the application, a heavy duty material is needed and sheet metal is very applicable in these scenarios.

It can be seen from the research that sheet metal approximately two to three (3) millimetres thick is utilised throughout these feeder bins depending on their size and application. Since this design is smaller in size and does not need excessive strength structurally a smaller thickness is all that would need to be used. This will also reduce the overall cost and make manufacturing more cost effective. This means the bin and the extended trip hopper section will be constructed from two millimetre thick sheet metal.

Likewise the frame that supports the overall bin construction will also be created from a small sized Square Hollow Section (SHS). This will also be a steel product due to its cost effectiveness and the availability. This product can be sourced locally and varies from 20 x 20 mm up to and including 400 x 400 mm, seen in Appendix I. To keep a standard thickness of two millimetres, the SHS will be approximately 25 x 25 mm and comes in lengths of six meters (Orrcon 2014). Costing of these lengths will be discussed further in the final costing of the concept.

The mounting plates on the legs will also be created by steel and should be significant in thickness so that the system remains firmly secured during operation. Five millimetre plate will effectively serve this purpose well and will only need to be large enough to house the leg and a significant sized mounting bolt or pin. This can be at the manufacturers digression and should not be highly considered as a crucial design problem initially.

The conveyor system will be sourced from a manufacturing company, Dorner, and the materials will not need to be considered for this analysis.

In conclusion the major materials to be used for this concept design is two (2) mm sheet metal for the overall bin structure and the frame is to be built using 25 x 25 mm SHS. Both these metal materials can be sourced locally and at an excellent price to try and keep the budget as low as possible. The most important consideration here is the structural integrity but also keeping the costs as low as possible for the benefit of the project objectives.

6.1.2 Manufacturing

To keep costs as low as possible the manufacturing of the device needs to be kept simple and effective throughout the build process. The manufacturing of the conveyor system will be outsourced to the manufacturers of the system and the belt modifications will be sourced through the conveyor company to keep costs as low as possible and so that the belt is fitted properly to the system before any mounting is done. Once the conveyor floor is sourced the main costs will then arise from the building of the shell and housing unit. As discussed previously the materials will be sourced and then used in the build. The initial prototype will be constructed manually by boiler makers. Due to the simplistic nature of the build, it would not be necessary to automate the building process, but rather, keep the construction in a workshop. Since the bin and frame is easily constructed from welding and the components are not of great size, one of two tradesman would be adequate for the construction of the prototype. If a jig system is created for mass production, the speed of creation will be greatly improved and should be considered once final testing has been completed.

By utilising manual construction methods and the use of MIG welders and workshop equipment the costs of the building process will remain as low as possible. The main expense being the use of tools (MIG Wire, Electricity and other incidentals) and the cost of labour. If manufacturing can be kept to the automated system completely built at an external location and the construction of the shell and frame in a boiler makers workshop, the cheapest manufacturing will be achieved.

6.1.3 Operator Instructions

The main objective of this particular project is to overcome the need for more than one operator throughout the whole process of feeding the livestock. It is most important that the machine is easy to operate and that this can be achieved from the comfort of the utility cabin. From this position the operator should be able to start and stop the machine by the press of a button. To add to the appeal for producers, there should be no instructions for operation due to the fact of its simplicity. Of course feeding rate charts and maintenance instructions will need to accompany such a system however the off/on operation should be simple and easy for the producer to understand.

Due to the system being operated by a single electric 12 volt motor the device can easily be wired to the utility and the attachment of a control box to the electric motor will create an easy and effective operating method. A simple button operated switchboard attached to this motor either via a handheld remote or by a hardwired switch in the utility cabin, the device should not be more complicated than this.

In the final concept it will be important to follow the electric control box approach as this will be the most cost efficient and easiest method to keep the system as simple for the producers to operate.

6.1.4 Mounting Device Methods

Due to the nature of the system, an important limitation to the final design is the ease of mounting the device onto a tray or trailer. For the producer to be able to handle the system on their own it is important for the device to have an easy process of lifting and alignment for securing. There are many approaches to mounting a bin onto a utility tray, some of these approaches are listed below and briefly explained.

1. **Bolting** - An extremely common method throughout agricultural applications. Due to the ability to simply drill a hole in the tray and have no other object hindering the flat surface, this is the simplest approach.
2. **Pipe and Pin** - The utility tray has four pins mounting by bolts onto the floor. The system has the four mounting points set up as pipe sections where the pins are lined up and inserted into the hollow pipe. Securing can either be by making the pins long enough so the system cannot jump high enough for the pins to exit the pipe or holes are drilled through both the pin and pipe and a bolt or pin is used to secure the pin inside the pipe.
3. **Pin and Plate** - The mounting pins attached to the utility tray are lined up to four holes in plates attached to the feet of the system being mounted. Once the pins are inserted through the holes in the plate, pins are used to stop the system jumping off the pipe.

Due to the nature of this system wanting to create a simple and easy alignment process so that two people are not necessarily needed the pin and plate approach proves to be most effective. Due to the ability for the operator to see and align the holes from the comfort of the lifting device. Since the plate has a flat bottom surface the pin will slide around the face until the hole is located. Once all four corners are aligned then the use of a ring lynch pin in all four mounting rods will be used for securing the system to the utility tray. A ring lynch pin can be seen below in Figure 6.1

Figure 6.1 - Ring Lynch Pin (Source: http://www.hisltd.co.uk/images/APerryLynchPinRing.jpg)

Initially four will used, however the design will have the ability to mount another plate onto the middle section of the exterior framework if the final prototype needs more stability and security. This mounting limitation will prove to increase the simplicity of the system as a whole and create a manageable way for producers to mount the machine alone.

6.2 Conceptual Design Sketches and Explanation

Throughout the design process, sketches were created to give better understanding on what the goal of the design was. Also they proved to be extremely important in the beginning stages of 3D modelling as they gave dimensions and orientation to the design being created. The importance of sketching has been shown throughout this project and has helped develop the design to where it is now. The sketches are all labelled accordingly and will be appropriately cross referenced throughout the discussion.

Shown in Appendix D through G are some of the conceptual sketches that were created in the process of creating the automated WCS feeder. For the ease of the reader to understand fully the concept these sketches were produced to give the reader initial visual depiction of what the design is visioned to look like. These appendices will be discussed further in the final prototype stage but should be referred to now so that the vision is clear before final models and drawings are produced.

6.3 Modelling Software Decision

It is important for this project to consider the possible design software packages and the advantages to each one. If the design is to be taken on by a company then it is extremely important that all design files can be taken throughout many different firms. It is important for the project to consider this in planning for the future. With this in mind, the most viable modelling software will be considered and chosen through a simple analysis.

6.3.1 Current Software Available

Through discussion with fellow engineers there are two major leaders in the 3D modelling software used in the professional environment and one leader in the university systems. These are listed below:

1. Autodesk Inventor 3D CAD
2. SolidWorks 3D CAD
3. Pro Engineer

The leader overall being SolidWorks 3D CAD, utilised worldwide in the modelling of a variety of systems. SolidWorks 3D CAD is a simple and effective package that can be used for many applications and deserves a high position in the industry for design drafting and modelling. This said Autodesk produces many software packages of a standard that is of high standards as well. Autodesk Inventor 3D CAD being a adequate clone of SolidWorks 3D CAD with not as many prominent features and less user friendly according to (Mason 2014) of Easternwell Toowoomba. Inventor boasts the ability to save into file types for SolidWorks to open and SolidWorks proves the same approach. This makes both software packages appropriate options for the modelling of the prototype design.

Pro Engineer seems to be a common software package in universities and schools due to the availability for educational licenses. Although Autodesk now gives students the ability to access all their software packages for free for students. Pro Engineer however useful in the educational field does not hold a high place in industry due to the fact that its competitors create such a great software package. Pro Engineer seems to be deemed the cheaper option in the industry as it cannot handle as complex tasks as its counterparts. With this said Pro Engineer holds its place well in the educational scene due to the fact that it can be sourced much cheaper than SolidWorks or Inventor. Inventor and SolidWorks hold a much more simplistic approach to the drafting process than Pro Engineer. Experience has given this insight into the three software packages. Since the project will need to be drafted for a more professional environment, Pro Engineer would not be an appropriate software package and should not be considered further.

6.3.2 Chosen Software Explanation

SolidWorks and Inventor hold the most appropriate stance for the modelling of the WCS Feeder. This project will utilise Inventor as the software package due to the ability to access a copy of the software for use in creating the draft model and dimensioned drawings. Autodesk now give student licenses for free making this package very useful in this application. SolidWorks would be an excellent choice as well but since access is impossible in the time frame, Inventor will be the software package used. The ability to save the file types into SolidWorks format makes this problem extremely minimal and the software used will not prove to cause dramas in the future of the project.

6.3.3 Conclusion

In conclusion, through the simple discussion of the available software in the industry and what can be sourced easily, the most accessible software package for the creation of the 3D model will be Autodesk Inventor Professional 2015. This software package will help the project produce detailed drawings for future consultations and give this report excellent visual aids for future consumers to view. The software package chosen will meet all drafting requirements and can be used in the future work on the project.

6.4 Modelling Software Concept Generation

The project has now reached a stage where modelling will begin. The importance of producing a proper 3D model of the system as a whole and its individual parts is important due to the need for dimensions and visual aids. Dimension will be utilised for the costing of the prototype and when final modelling stages are completed, sheet metal area and system components can be sourced and planned accordingly. By creating a professional 3D model of the system the project will be able to give effective visual aids for future reference. Another benefit to the generation of a model is the ability to then produce manufacturing plans and exploded views for the assembly line. By using 3D modelling software all the requirements for final prototype building can be produced and easily accessed for future project work.

Initially the plans for modelling the system will be discussed briefly to give an outline of how the final concept will be generated. It is important to follow a plan to meet the final time deadline for final detail drawings and costing. Once an effective plan has been discussed and created, the project will then display and discuss the final conceptual drawings of the design and give a final 3D model of the design prototype to be created. The final stages of the design will be covered in chapter seven and involve the final stages of costing and manufacturing the prototype.

6.4.1 Initial Plan for Model Generation

The initial model will consist of the exterior bin and the reinforced structure containing the bin. This exterior webbing will be used to mount the whole system onto the utility tray and will give the structure integrity. By creation of this shell feature and external bracing in the modelling software to actual size it will prove to be very useful in the design of component placement. The bin design shown in Appendix D displays an incline that will aid the movement of the WCS as it is fed out the conveyor. Once the model shell has been created, the best angle of attack and size of the conveyor floor will be sourced. Through calculation and modification of the model, the ideal size for appropriate feed amounts will be sourced. Once the initial shell and interior systems are generated, then exterior chute and lid will be modelled. These particular components are not important for the initial stages of generation but will prove to give effective visual aids for final presentation.

Once the final concept is complete, if time allows, modelling of electric motors and chain systems will be conducted to help produce final conceptual drawings with proper component placement. These components will be generated to size but complexity will not be important. This means that sprockets and chains will be depicted by accurate pulley and rope shapes. This will cut back time to produce the final touches on the device but will still give viewers an accurate depiction of the final prototype.

Due to the tight time constraints of the project, the modelling will be kept as basic as possible so that dimensions and final drawings can be created. The visual aid of the final concept model in 3D will provide manufacturers and potential customers the ability to see the design and analyse its potential benefit to their operation. The final detail drawings produced from the model will be able to provide manufacturers and material suppliers proper dimensions. It is important for the project to follow dimension limits and the limitations of the materials. The most important conclusion is that the aims of the project are met.

6.5 Final Conceptual Drawings

At this stage of the design, preparation for manufacturing and building of the prototype needs to be clearly stated and understood. The following discussion will cover all the important factors of the conceptual drafts and explain in the detail the layout of the system. Initially the conceptual sketches will be discussed and then discussion of the modelling process and the final detail drawings. These final drawings and sketches will all be displayed in the appendices at the end of the report and will be referenced to throughout the discussion. Included in these sketches and drawings will be process screen shots of the gradual modelling process of the concept. This will give an accurate history of the model development. Finally the most crucial isometric depictions and their accompanying detail drawings will illustrate the final layout. These isometric and detail drawings will also provide crucial dimensions and give a clear demonstration of what the final concept will aim to look like. The overall dimensions in these drawings will provide key limitations for initial construction but will not be final until the prototype is completed the construction stage. It is important to keep the design open to future modification after intensive testing.

6.5.1 Sketches and Detail Plans

Through the use of sketches and detail plans, the generation of the final 3D model will be optimised and easier to achieve in the tight final timeline. As seen from Appendix D through G the initial sketches of the concept give general dimensions and through material analysis finalises all the necessary information to create a general layout of the concept and give an excellent presentation of what the final design will aim to look like.

Appendix D shows one of the initial design sketches that was used to mock up initial dimensions and orientation before calculations were made to verify the overall size. This is of course a rough sketch to give initial vision to the project and guide how this design aims to meet design constraints.

Appendix E shows a much more detailed view of the system and how it will be initially orientated. The most important factors to note here are the dimension changes (still within design limits) and the introduction of the drive systems and locations of the trap door dispenser. These dimensions have been calculated to best suit the projects initial scenario and will be open to modification as the design is improved throughout the testing stage. An important thing to note here is the initial scenario is to house approximately 800 kg for a small scale farm. The different sizes are outside the scope of this project and will not be considered.

Appendix F shows a detailed top view of the system and the appropriate dimensions needed for the 3D modelling phase. The detail sketch displays the orientation of the components and where they should be located for initial prototyping.

Appendix G shows the layout of the dispenser unit and how the project aims to achieve the portion dispersion. The most appropriate approach is to utilize a swinging arm that opens the door before it swings past its reach and the spring acts to close the door swiftly behind the device. As seen in the sketch the device is to be driven by the main axle that is driving the main conveyor system, however the arms needs to be reduced in speed for the accurate portion sizes to be dispensed. This design will allow for many different improvements like the use of different sprockets to create different spaces between the portions or by changing the speed of the conveyor to fill the unit more before a portion is dropped. These modifications can easily be achieved by changing the sprocket sizes on the drive motor and also on the swing arm.

These basic sketches give merit to the final design and show the initial phase of concept generation. The importance of this stage is very apparent when the final modelling process is undertaken. If the correct geometry is calculated and sketched first then the process of reproducing the sketch becomes exponentially greater. It is important that the sketching stage is completed not to only benefit the project in the final stages but to also give a visual story of the concept creation. Their visual aid is important to the project and was beneficial throughout final stages.

6.6 Conclusion

Throughout the discussion into the various limitations of the conceptual design and analysing the various approaches in finalising the design the project can be better prepared for this final stage of implementation. It is extremely important for each of these discussed topics to be followed so that the final conceptual design follows a plan and meets the demands of the project in the given time frame. By following these limitations and guidelines the timeline will be met and also take into consideration the initial design constraints and guide the drafting process throughout the final stages. By giving the project limitations in manufacturing and materials makes the final costing of the machine effective and well guided.

Finally through the use of sketches and detail plans of the conceptual design it can be easily seen how the final concept will be produced and will give helpful references throughout the final model generation. Without these visual aids to display the concept evolution the project has no history to be shown. The concept history displays how the project evolved throughout the discovery of the guidelines and also gives a brief insight into where the idea originated throughout the research into the existing systems and also how the model aims to look after final stages of design. Of course these will give rough estimates but the final model should look comparatively similar to the sketches in an overall form.

Once the final model is drafted using these guidelines, a final costing will be conducted taking into consideration the materials and manufacturing methods discussed previously. Once the costing has been completed a final recommendation will be undertaken will an overall cost and a completed model for visual accompaniment.

7 Prototype Specifications

The following chapter will aim to finalize the design project, giving a variety of drawings, calculations and plans for the final prototype. These will conclude the design process and lead to a final prototype. Keeping in mind that the final prototype will be utilised for costing and implementation purposes, the final manufacturing process may need more optimisation and overview before a final prototype is constructed for testing. By covering the drawings, calculations, costing and implementation plan, final conclusions will be available and will be drawn to guide the future progress of this project beyond the scope of the current objectives.

7.1 Final Prototype Drawings and Calculations

To benefit the project, a final discussion into the calculations and drawing of the final prototype will be undertaken to give final clarification on where the final design is at and how it will fulfil the final objectives of the project.

7.1.1 Prototype Calculations

The final prototype creation in the modelling package was implemented to give visual aid and initial dimensions for the prototype. These dimensions will be most important when estimating the component costs to follow.

It is important at this stage of the design to cover the final prototype drawings and display the calculations that prove the dimensions will work for the application. These calculations will be shown after discussion of the final prototype drawings and will simply be used to give mathematical merit to the chosen design dimensions.

After discussion of the appropriate amount of feed that needs to be discharged per portion it was discovered that a portion between 12.5 - 15 kg. It was also discovered for the specific application being discussed by this project, a storage bin that can adequately hold over 500 kg for a small herd application. This prompts calculation to confirm that the dimensions given for the prototype will adequately hold the needed amount of feed and also the trap door dispenser can hold double the portion size so that there is room for error and optimisation. The trap door dispenser unit will be mounted either on the driver's side or the passenger side of the vehicle. Since the system will be marketable worldwide the simplest approach is to make the system mountable in both orientations so that the driver can monitor and adjust the device from their applicable side.

To prove that the given dimension will meet the requirements, some general volume calculations are given below for reference.

Overall Capacity:

Density of WCS = 400 kg/m^3

Volume (Bin Capacity)	*= Length x Width x Height = 1.9 x 1.0 x 0.9*	*= 1.71 m^3*
	= 1.71 x 400	*= 684 kg*

Trap Door Dispenser Capacity:

Volume (Chute Capacity)	*= Length x Width x Height = 0.4 x 0.4 x 0.4*	*= 0.064 m^3*
Needed portion of 15 kg	*= 0.064 x 400*	*= 25.6 kg*

These simple calculations prove that the given prototype dimensions meet all the requirements of the design and will implement a good margin for optimisation and testing.

7.1.2 3D Prototype Creation

As previously discussed, one of the main objectives for this research project was to create a 3D model of the prototype for future analysis and creation. The modelling was undertaken in Autodesk Inventor Professional 2015. This software was extremely user friendly and was helpful throughout the modelling process. In Appendix J two initial skeletal view of the prototype can be seen. The top view shows the initial design for the dispenser unit however after research and general structural advantages the idea was revised and can be seen below the initial figure. These are the first representations of the design and display the basic structure of the system. It can be seen in these views that a few more structural braces have been added to the initial sketch. These were added due to the need for higher structural integrity. These additions will increase strength and give appropriate support to the storage bin.

The initial drawings shown and the final 3D model shown in Appendix K have further work to be completed but give an excellent guideline for the final prototype development stage. Appendix K displays the final layout that will be finally testing once creation has been completed. This design will be able to utilize the conveyor system and test the system for optimisation and effectiveness. The model displays the mounting braces and holes for the conveyor system and the electric motor. The additions features yet to be completed are the mounting points for the swing trap door and the spring for door closing. These will be need to be added in future work along with the drive system and motor. These components were not available for drafting at this stage but will be available for future work.

The final detail drawing shown in Appendix L is to give some overall dimensions and views of how the design will look as a skeletal feature. Due to the time constraints of this project, the parts could not be implemented in the final detail drawing due to the inability to draft these complex features but will be an excellent future project to finalize the drawing and begin testing. The design has plenty of room for all the proposed features and by installing all the appropriate features in the testing stage will give final dimensions on prototype drive placement.

These final drawings will guide the future work in the building stage and are a great foundation for the development of a system that proves to be applicable to this application.

7.2 Estimated Component Costs

The overall prototype will need a list of all components and the general cost for each to finalize a total figure for recommendations and conclusions. A materials list can be seen below in Table 4 and gives the overall needs for prototype construction; also the price and total dimensions can be seen. This list allows for waste and general tolerances in the measurements so that there is enough materials. The calculated lengths can be seen below:

Skeleton Frame (25 x 25 mm SHS) :

6.0 x 2.0 m Lengths	*= 12.0 m*
6.0 x 1.0 m Lengths	*= 6.0 m*
Total	**= 18.0 m**

Bin Walls (2 mm Sheet Metal):

2 x (1.0 x 1.3 m) = *(2.0 x 2.6 m)*

2 x (2.0 x 2.0 m) = *(4.0 x 4.0 m)*

4 x (0.6 x 0.6 m) = *(2.4 x 2.4 m)*

Total **= (8.0 x 9.0 m)**

Mounting Plate (5 mm Plate)

4 x (0.1 x 0.1) = *(0.4 x 0.5 m)*

Total **= (0.4 x 0.5 m)**

From these total dimensional values for the materials, a quotation can be gathered to give the project a materials cost for future reference. These values can be seen in the Table 4.

Table 4 - Materials List

Material	Calculated Length	Estimated Cost
25 x 25 mm SHS	18.0 m	$19.45 inc per length
2 mm Sheet Metal	8.0 x 9.0 m	$75.00 inc ($110.00 for 3 mm)
5 mm Plate	0.4 x 0.4 m	$100.00 inc. (6.0 m x 6.0 m)

The mounting plate comes only in large sheets meaning the best alternative to buying a large sheet is welding off cuts of the wall sheets or finding scrap materials and utilising them.

In Table 5 below, the final overall component costing can be seen. These figures give a consistent guideline that will be effective in the future considerations of the design.

Table 5 - Component Costing

Component	Estimated Cost (AUD)	Availability
Skeleton Frame (25x25mm SHS)	$60.00	IN STOCK
Bin (2 mm Sheet Metal)	$75.00	IN STOCK
Conveyor System	$4000.00	ORDER IN
12V Drive Motor	$1000.00	ORDER IN
Trap Door Dispenser (2 mm Sheet Metal)	--- INCLUDED IN BIN CALCULATIONS----	
Incidentals	$250.00	
TOTAL	$5385.00	

In conclusion the overall costs fall well inside the budget allowing for some under budgeting, particularly regarding the drive motor. Due to the huge market, the average high torque electric motor can be sourced for around $1000.00 AUD but depending on the reliability of the particular brand will change the price drastically. These guidelines give an overall cost for final consideration and can be used in future analysis and reference.

7.3 Implementation into Farming Practice

After the final prototype has been analysed and manufactured, implementation into the farming practice needs to be considered for future investment of the project into the agricultural field. It is important for the implementation process to be considered before final construction and testing because a plan to market and promote the product needs to be considered.

First of all marketing the product is most important in implementation of the design. By sending out the final design prototype drawings and test results to a variety of agricultural companies, the idea and concept will become known to the specific audience. By firstly concentrating on the Australian market and then utilising the abundant American market the product stands in good stead to be recognised. The important steps to marketing such a device are the initial steps to getting to product known to the right people. By utilising the drought relief market and the Australian agricultural industry, getting the product known should not prove too difficult but getting the product accepted will prove challenging.

The second most important factor in implementation is finding the company to financially back the design and take the testing of the prototype onboard. Once financial support is achieved, the design can be optimised and tested under various conditions. Mass manufacturing can then be utilised to create a worldwide available product. The importance of building respectable relationships with the various companies researching in the agricultural field is most important for this stage. By again sending the design to a variety of companies and getting the device known will prove helpful in receiving financial support.

Finally once the product is known throughout the industry and sponsored by a company willing to optimise the design and test the prototype the final product can be manufactured to meet the potential demand in the industry. By implementing the design throughout the Australian and American industry the larger the chances are of the design taking off in the market. By slowing implementing the product and not overproducing in the beginning is key to a successful introductory period. By carefully consulting the need of the product in that specific season is important for this to happen successfully.

By the use of marketing, financial support and extensive testing, the design has the potential to take on the agricultural market and be effectively implemented into the many applications throughout the world.

7.4 Plan for Construction and Testing

The final stages of this project is construction and testing. Due to the time constraints of the project this cannot be achieved initially but will be planned for. Due to the size and nature of the system sourcing the components and building will definitely take a sizable budget and significant manufacturing time which this project is lacking of. The design is now at a final stage where all the dimensions have been chosen and the materials to create the whole system have been sourced and priced. This gives an excellent starting point for the construction work to begin.

Initially it is important for all materials to be cut to size and the system components to be purchased. This will be the first stage of the construction stage. Once all the components and materials are gathered the initial cutting and bending stage will be undertaken. It is most important for the storage bin and frame to be completed before any other components are added. Once the structure is completed, fitting the conveyor system into the bed of the bin will take place. This is where testing and modification of the belt can be undertaken. The vision of the project will need to be critiqued at this stage to make sure all guidelines are being followed and the system proves worthy to continue with construction.

Once the bin and conveyor system are fitted then the driving components will be implemented. This stage is where the best fit location for the drive motor and wiring can be identified. This stage of the construction will be important for the proper operation of the system. Once the best motor location is identified and mounting has been completed, final wiring to power will be completed and fastening to the utility. At this stage running the device is will need to take place before running any produce through the system. Fine tuning the operation will weed out any problems before introducing the WCS for testing.

Once the system has been tested operationally, then introduction of WCS will take place. This is where testing will be rigorous on how the system meets the requirements of the design and whether all the goals are achieved. The device is prone to optimisation at this stage. If the device responds well to WCS, as proposed, then the project device will be appropriate for mass producing and marketing for sale. This will be the final stage of the project and is not of importance at this stage.

The final prototype construction will include substantial testing, however at this stage, is very well prepared for this to happen and will provide any interested parties the ability to complete a substantial final system to automate the feeding of WCS.

7.5 Conclusion

By the use of sketches, detail drawings, component costing, a description of the implementation process and a construction plan, the final proposal has been generated. With the costs and availability given, it is simply a matter of contacting the appropriate companies to start the construction phase. The components can be sourced from the appropriate companies and be implemented into the final prototype for final testing. It is important for the design to incorporate all the discoveries and follow the sketches created for ease of generation. From the finding of this chapter, a more accurate estimate of the final prototype cost and implementation is now better understood and will be more achievable in the future work. Final consultation with the appropriate companies may prove to benefit the project through discounts and over budgeting.

8 Conclusion

8.1 Conclusion

This research project set out to analyse and compare the current methods of feeding out White Cottonseed to livestock and how this method could be improved through automation. By compiling an extensive literature review discussing why there is a need for such a product and whether one is currently being utilised in today's world led to the discovery of a possible new innovation for the agricultural industry. By finding and comparing the various approaches being used and identifying the most effective ones for the application at hand, the generation of a concept was made to solve the problem being faced.

Once a critical analysis was done on the various approaches, each one was scored to find an overall winner in this application; this was the conveyor belt system. This system was then analysed for optimisation in handling White Cottonseed as a raw product and a simple design was created. The substantial design limitations created were used to govern the conceptual generation and gave guidelines for the project to propose a solution.

The proposed solution for this particular problem is the use of a mountable storage bin with a modified conveyor belt floor. The conveyor system will have the option for two test modifications given throughout the discussions and with testing should result in a solution. The portions will be governed by a spring loaded trap door dispenser unit located at the end of the conveyor run. This will contain between 12 and 15 kg of WCS and will be opened by a rotating arm. The arm will be driven by a chain gear attached to the main drive shaft however the gear on the arm will be proportionally larger so that the conveyor can fill the unit before the arm opens the door.

Through a final cost analysis the system will sit nicely in the proposed budget and has plenty of room to move with changing expenses and/or additional modifications to the drive system or storage system. The total cost for the initial build will be approximately $5400.00 AUD and can be built as soon as parts are received after ordering.

The final conceptual sketches and model can be seen in the appendices and give a good visual aid to how the design should look after building.

Through the in-depth analysis of new systems and current methods of feeding livestock an appropriate solution has been found for prototyping and testing.

8.2 Recommendations for Future Work

To excel this project further into the applicable field there needs to be more work completed. The main objectives of the project have been completed however there is still some final work to be done, which include;

- A more detailed and accurate 3D model is to be completed for final drafting purposes. The final model for this analysis was not a extensive as originally planned but due to the time constraints, the final drafting time was underestimated. The plans for the design should be completed to a standard ready for building rather than the use of a visual aid. The model should include tolerances and all materials required giving the manufacturers and interpreters everything they need to know to complete the prototype.
- A more detailed cost comparison in drive motor and conveyor system. Due to the nature of the project, companied were limited in their help, however with a final design in place an extensive shop around will need to be completed for a most cost effective solution.
- Testing of the prototype and optimizing its performance. The two conveyor options and drive motor gearing will be tested here to optimize feed rates and to gear the opening arm for correct dropping rate. The testing stage will be crucial to design optimization and improving performance
- Marketing the system will be the last stage in the future work. This will only be able to be fully completed once the design has been fully tested, optimized and accurate plans have been produced.

These points summarize the final stages of the project which were outside the scope of this particular project. By utilising the 3D model created and material list, the prototype can be created for future testing and optimisation by another.

Through the use of research and critical analysis an appropriate design concept has been created to meet the demands of this project. By implementing this solution into the farming practice the producer has the ability to assess his livestock without leaving the comfort of the vehicle he is travelling in. This not only will benefit his overall comfort but also will make the process of feeding his livestock a more cost effective method. By speeding up the process of feeding out White Cottonseed, by at least five times, the producer will save valuable time. The ability to save time opens up more opportunity to complete other tasks. Saving time also reduces the fuel consumption of the feeding process but also reduces the cost of labour. If a producer has an employee that does the feeding, then costs are lowered as the hours required for the job is reduced.

It is recommended to implement such a device as it is not only cost effective but also less physically demanding on the producers. As discussed, the current methods include the use of shovels. By taking this physical side of the process away means that the job can be achieved by older producers. This makes the product particularly marketable to the older generation of farmers that still wish to run cattle on their property but find the feeding process to difficult. By having such a system that does the job for them, not only for White Cottonseed but various other feeds as well, will appeal to such a generation.

Having the feeding device on the utility means that feeding livestock in remote areas can be easily achieved and no additional troughs or feeders are needed. This benefits producers as they can run out to the livestock and feed them while checking their health.

The benefits of this system greatly outweigh any cons and the solution found proves to be very useful in this application. It is recommended that such a device be prototyped for extensive testing and optimisation in the near future so that this device can benefit producers throughout Australia and even worldwide.

References

Agquip, C 2014, *Mobile Feed Out Bin*, Commander Ag-quip, viewed 16th September, <http://www.commanderagquip.com.au/products/1ton-silo-mobile-feed-out-bin-with-tarp>.

Australia, C 2014, *The Australian Cotton Industry*, Cotton Australia, viewed 16th May, <http://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-the-australian-cotton-industry>.

Australia, MAL 2014, *Cattle*, viewed 14th March, <http://www.mla.com.au/Cattle-sheep-and-goat-industries/Industry-overview/Cattle>.

Autodesk 2014, *Inventor*, viewed 21st August, <http://www.autodesk.com/products/inventor/overview#>.

Baines, A 2014, *3 Series Loader*, Vanderfield, 28th April

Blackwood, I 2007, *White Cottonseed - A Supplementary Feed for Beef Cattle*, NSW DPI, 17th March 2014.

Blasi, DA & Drouillard, J 2002, *Composition and Feeding Value of Cottonseed Feed Products for Beef Cattle*, Kansas State University, Kansas,<http://www.ksre.ksu.edu/bookstore/pubs/mf2538.pdf>.

Bowman, J 2014, *Cotton Seed Feeding*.

Grainbelt, 2013, Created By.

Corp., DM 2013, *1100 Series End Drive Conveyors*, Dorner MFG Corp., 9th August

Corp., S 2014, *3D CAD Packages*, Dassault Systems viewed 21st August, <http://www.solidworks.com/sw/products/3d-cad/packages.htm>.

Cotton, Q 2014, *Contact Us* OLAM, viewed 2nd May, <http://www.qcotton.com.au/Queensland-Cotton.html>.

Cottonseed 2014, *Benefits Of Feeding Cottonseed*, Cotton Seed, viewed 25th April, <http://www.wholecottonseed.com/cottonseed-101/benefits-of-feeding-wcs>.

Cotton Module Staging Instructions and Truck Requirements, 2013a, Created By.

Deere, J 2013b, *3 Series Front Loaders*, 11, 27th March 2014, Brochure, <https://www.deere.com/common/docs/products/equipment/frontloader/brochure/frontloaders_0814702_en.pdf>.

Department of Agriculture, FaF 2012, *Whole cottonseed for survival feeding of beef cattle*, Queensland Government, viewed 21st March, <http://www.daff.qld.gov.au/environment/drought/managing-drought/drought-strategies/whole-cottonseed-for-survival-feeding-of-beef-cattle>.

Dictionary.com 2014, *Drought*, Dictionary.com, viewed 17th March, <http://dictionary.reference.com/browse/drought>.

Dorner 2014, *Standard Conveyor Products and Systems*, Dorner Services, viewed 9th August, <http://www.dornerconveyors.com/Products.aspx>.

Fabrications, S 2011, *Feed Dispensers*, Southwest Fabricators viewed 9th May, <http://www.overheadbins.com/gallery3.htm>.

Feeders, A 2014, *Advantage Feeders*, Advantage Feeders, viewed 31st March, <http://advantagefeeders.com.au/advantages>.

Feeders, TS 2012, *Trip Hopper Range Cattle Feeders*, T & S Mfg. Inc, viewed 9th May, <http://www.tsfeeders.com/>.

Florida, Uo 2013, *Whole Cottonseed for Beef Rations*, EDIS, viewed 14th April, <http://edis.ifas.ufl.edu/an134>.

Government, A 2014a, *About Droughts*, Couch Creative, viewed 17th March, <http://schools.aemi.edu.au/drought/about-droughts>.

Government, A 2014b, *Drought*, Bureau of Meteorology, viewed 4th April, <http://www.bom.gov.au/climate/drought/drought.shtml>.

Government, N 2009, *Grain Augers*, 24, 9th April, Brochure, <http://www.commerce.wa.gov.au/worksafe/PDF/Misc/Grain_augers.pdf>.

Henderson, A 2014, *Drought-hit farmers get chance to show Tony Abbott parched communities first hand*, ABC News, viewed 4th April, <http://www.abc.net.au/news/2014-02-16/tony-abbott-touring-drought-affected-nsw-qld/5262776>.

Easiflo Cottonseed, 2001, Created By, Cotton.

Feeding Cottonseed and Cotton Byproducts to Beef Cattle 2001, Created By.

Lengerich, Bv 2014, *V Mix Plus*, BvL Industries, Germany, 16th May, Flyer, <http://www.bvl-group.de/company/CMS/cms/upload/Landmaschinentechnik/PDFs/Flyer-V-Mix_UK_3Aufl.pdf>.

Manufacturing, B 2014, *Feed Dispensers*, Bar6 Manufacturing, viewed 9th May, <http://bar6.net/feed-dispensers/>.

Mason, S 2014, *Inventor VS Solidworks*, Damien Wooldridge.

McLennan, SR, Plasto, AW, Doogan, VJ & Dillon, RD 'Whole Cottonseed and Cottonseed Meal Supplements for Cattle given a Hay based diet', vol. 1, p. 4, viewed 4th April 2014.

Moore, M 2014, *Landcruiser Tray Sizes*, South West 4WD, 1st August 2014.

Morgan, S 2013, *Gossypol Toxicity in Livestock*, Oklahoma Cooperative Extension Service.

Mulhare, S 2014, *Small Scale Cattle Operation*.

Norrish 2014, *Equipment*, Norrish Service Group, viewed 7th October, <http://www.norrish.net.au/chaser-bin.php>.

Orrcon 2014, *Square Hollow Section*, Orrcon Steel, viewed 7th October, <http://www.orrconsteel.com.au/australian-steel-products/tube-and-pipe/structural-steel/SHS>.

PWC 2011, *The Australian Beef Industry*.

Ranch, TF 2014, *Heavy Duty Cube Feeder*, Tartar Farm and Ranch Equipment, viewed 9th May, <http://tarterusa.com/tarter-products/heavy-duty-cube-feeder/>.

Riverina 2013, *Whole Cottonseed*, Riverina, viewed 14th April, <http://www.riverina.com.au/website/files/product_manual/Page%20I151%20-%20Whole%20Cottonseed.pdf>.

Rolston, B 2014, *Auger and Conveyor Costing*, Ahrens Group.

Stewart, L 2010, *Using Cotton Byproducts in Beef Cattle Diets*, University of Georgia.

Today, C 2011, *Calf Scours*, Cattle Today, viewed 4th April, <http://cattletoday.info/calfscours.htm>.

Travers, J 2014, *3 Series Loader*, Vanderfield

Wedegaertner, T 2014, *Easiflo*, Tom Wedegaertner.

Willcut, HM, Mayfield, WD & Valco, TD 1997, *Cottonseed Storage*, Cotton Incorporated.

Willcut, HM, Mayfield, WD & Valco, TD 1997, 'Cottonseed Storage', p. 1, viewed 27th August, <https://www.cotton.org/ncga/techpubs/upload/Cottonseed-Storage.pdf>

Wood, AG, Bolam, MJ, Krebs, GL & Andresen, AR 'Whole Cottonseed as a supplement for Weaner Cattle Offered Pangola Grass Hay', vol. 1, p. 5, viewed 4th April 2014.

Wooldridge, D 2014, *Cotton Seed Feeding*.

Appendices

Appendix A - Project Specification

ENG 4111 / 4112 Research Project

PROJECT SPECIFICATION

STUDENT: **Damien Wooldridge**

TOPIC: Feeding out cottonseed to livestock

SUPERVISOR: Dr Guangnan Chen (USQ)

ENROLMENT: ENG 4111 – S1, X, 2014

ENG 4112 – S2, X, 2014

PROJECT AIM: Cottonseed is a by-product of cotton production. It is often sold to livestock producers as drought supplementation feed. The purpose of this project is to develop an improved method to feed out cottonseed to livestock.

SPONSORSHIP:

PROGRAMME: 7^{h} February 2014

1. Research existing information relating to machinery used for feeding out cottonseed to livestock in the world. This would include a literature review of alternative design principles.

2. Identify and develop suitable design specifications.

3. Develop and cost an improved prototype using a commercial solid modelling program. Designs should incorporate purchasable items and manufacturable parts.

As time permits:

4. Construction of the prototype for testing.

AGREED:

_______________ (Student) _______________ , _______________ (Supervisors)

___ / ___ / ___ ___ / ___ / ___ ___ / ___ / ___

Appendix B - Cottonseed Feed Products for Beef Cattle

K-STATE
Kansas State University
Research and Extension

Composition and Feeding Value of

Cottonseed Feed Products for Beef Cattle



Kansas State University Agricultural Experiment Station and Cooperative Extension Service

Introduction

For more than 200 years, cotton has played a key role in the history and development of American agriculture. This important dual-use crop produces not only lint that is used to clothe the world's increasing population, but also a variety of nutrition products such as cooking oil, cottonseed meal, and hulls that benefit both consumers and livestock.

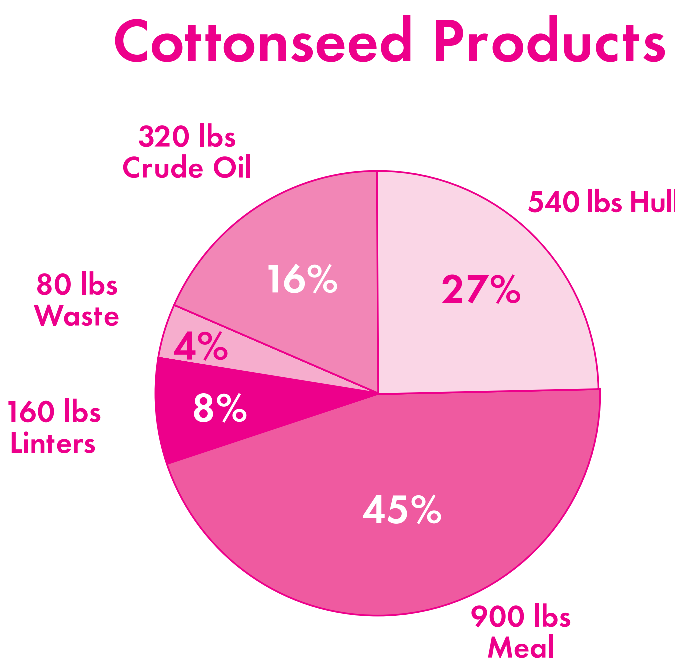
The invention of the cotton gin by Eli Whitney in 1793 resulted in the accumulation of cottonseed. It was used as a source of planting seed, but not for its nutritional value until the 1800s. Today, the value of cottonseed represents about 18% of a cotton producer's income.

For a variety of reasons, the percentage of cottonseed destined for crushing has steadily declined from a high of about 90% in 1950 to an estimated 45% in 2000 and 2001 (USDA, 2000b). The unique protein, energy and fiber content of whole cottonseed has resulted in its popularity as a staple component in dairy rations. The price and availability of whole cottonseed depends upon the size of the cotton crop and oil demand, as well as competition for positions in the market during harvest.

Figure 1 illustrates the respective yield of each by-product produced for each ton of cottonseed that is crushed for oil and meal purposes. Linters, the short fibers still attached to the seed after the ginning process, represent about 8% and are used by several manufacturing industries to produce a variety of industrial products. The crude oil fraction represents about 16% before it is refined to produce an edible oil. The hulls and meal represent almost three-fourths of the crushed cottonseed and are used primarily as feedstuffs for livestock.

This publication contains information related to the nutrient composition and feeding management of whole cottonseed, cottonseed meal and hulls. This will help beef producers capitalize on the opportunity to use cottonseed by-products, where opportunities exist, reducing costs of production.

Figure 1. Cottonseed products yield per ton of seed crushed[a]



[a] National Cottonseed Products Association, 2000

The Cottonseed Crushing Process

Whether cottonseed is bound for direct use in dairy and beef cattle rations or for oil extraction in crushing plants, it must be handled and stored properly to maintain seed quality. A simple flow chart of the cottonseed crushing process and the by-products that result at each step are illustrated in Figure 2.

Cleaning – The initial step in crushing involves passing the cottonseed through a series of screens that revolve and shake to remove extraneous material such as leaves, stems or dirt.

Delinting – After the removal of foreign matter the attached short fibers, known as linters, are cut by machines similar to gins, but with circular saws and finer teeth, and pneumatically removed through a series of revolutions. This creates various grades of linters that are classified by length and composition. For example, most seed is circulated through the system twice to produce first-cut and second-cut linters with proportions that may vary within limits (NCPA, 2000).

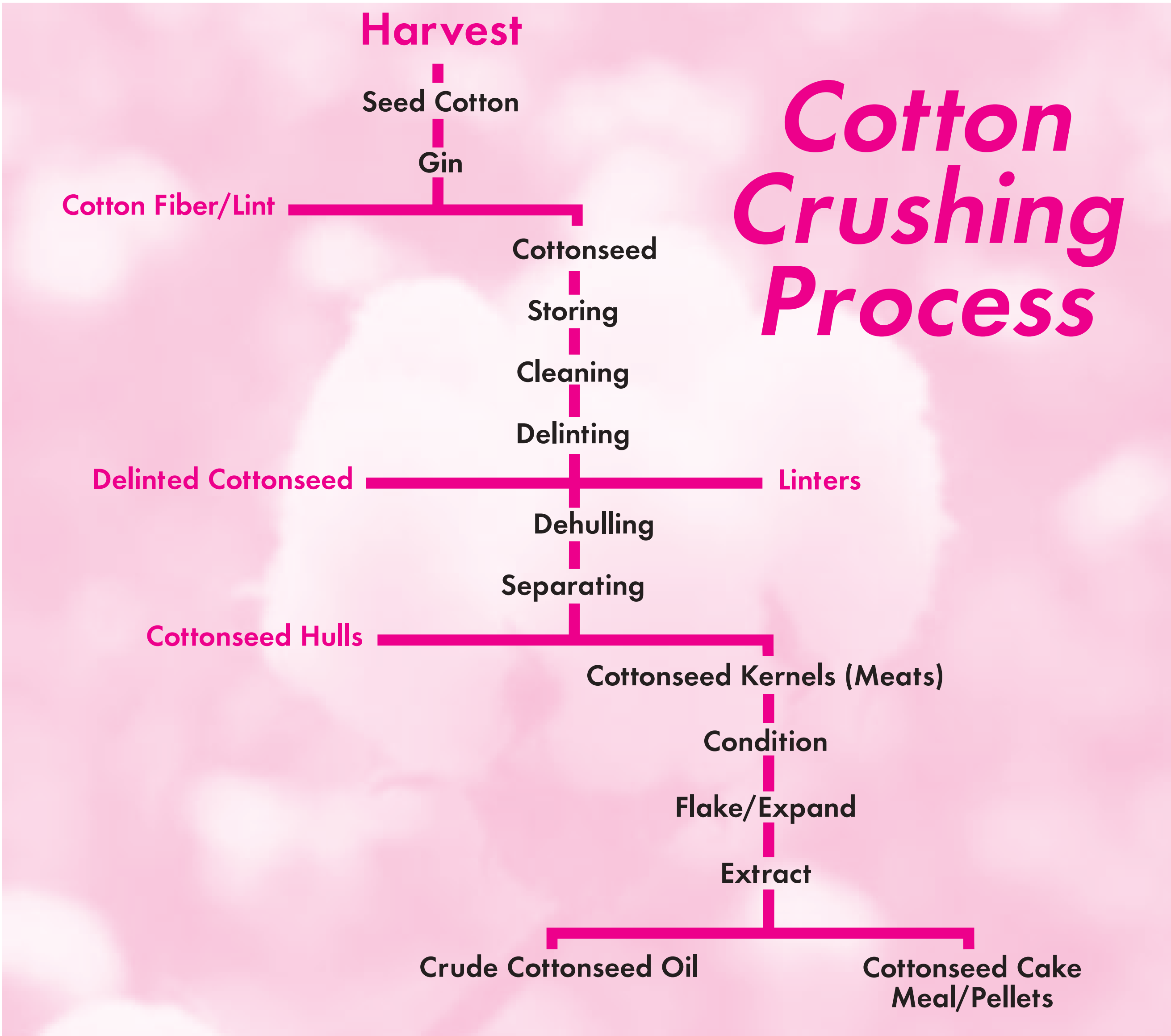
Hull removal – Once the seed is delinted, it is dehulled using a machine outfitted with a series of knives which progressively nick the hulls, loosening the tough outer covering surrounding the cotton meat. An additional series of shaker screens helps facilitate the separation of the hulls from the meat. Once this step is complete, the hulls can be marketed either in bulk or pellet form as a sole ingredient, or blended with approximately 35% cottonseed meal to produce a product that offers distinct advantages in terms of transportation, ease of handling and protein content.

Kernels – The remaining seed meats are conditioned to an appropriate temperature and moisture content for the final flaking step. Then they are passed through a set of rollers with the intention of creating flakes .01 to .015 inches thick, which is optimum for handling during oil removal by mechanical pressing or solvent extraction. Expanders have been introduced into the solvent process, which helps dramatically reduce free gossypol levels (Calhoun et al., 1995a).

Oil extraction – Oil is extracted from the flakes with an organic solvent, usually hexane, and reclaimed to yield crude cottonseed oil, which then undergoes an initial refining process to separate the free fatty acids from the oil. The extracted cottonseed oil is further refined to produce products such as cooking oil, margarine and shortening. During the extraction process, the oil content of the flakes is reduced to less than 0.6%. The defatted flakes are desolventized, toasted and ground into meal.

Cottonseed meal formation – Refinery by-products are then added back to the meal to increase its energy content. After leaving the desolventizer-toaster, the flakes are referred to as cottonseed meal. This meal is transferred to a meal dyer where it is further dried to approximately 10% to 12% moisture. After drying, the meal may go through a cooler, where it may be ground into meal or processed into pellets.

Figure 2. Cottonseed Crushing Process



Description Of Cotton By-products

The following international feed numbers and descriptions of cottonseed by-products were obtained from the Association of American Feed Control Officials (AAFCO, 2001).

24.10 **Cottonseed Meal, Mechanical Extracted** is the product obtained by finely grinding the cake that remains after removal of most of the oil from cottonseed by a mechanical extraction process. It must contain not less than 36% crude protein. It may contain an inert, nontoxic conditioning agent either nutritive or non-nutritive or any combination thereof, to reduce caking and improve flowability in an amount not to exceed that necessary to accomplish its intended effect and in no case exceed 0.5%. The name of the conditioning agent must be shown as an added ingredient. The words “mechanical extracted” are not required when listing as an ingredient in a manufactured feed. (Proposed 1984). IFN 5-01-625 Cotton seeds meal mechanical extracted 36% protein.

24.12 **Cottonseed Meal, Solvent Extracted** is the product obtained by finely grinding the flakes which remain after removal of most of the oil from cottonseed by a solvent extraction process. It must contain not less than 36% crude protein. It may contain an inert, nontoxic conditioning agent either nutritive or non-nutritive or any combination thereof, to reduce caking and improve flowability in an amount not to exceed that necessary to accomplish its intended effect and in no case exceed 0.5%. The name of the conditioning agent must be shown as an added ingredient. The words “solvent extracted” are not required when listing as an ingredient in a manufactured feed. (Proposed 1984) IFN 5-01-632 Cotton seeds meal solvent extracted 36% protein.

24.14 **Ammoniated Cottonseed Meal** is obtained by the treatment of cottonseed meal with anhydrous ammonia until a pressure of 50 pounds per square inch gauge is reached. It is to be used in the feed of ruminants as a source of protein and/or as the sole source of non-protein nitrogen in an amount not to exceed 20% of the total ration.

The label of the additive and of any feed additive supplement, feed additive concentrate, or feed additive premix prepared from it, must contain the following information in addition to any other required information:

1. The name of the additive
2. The maximum percentage of equivalent crude protein from non-protein nitrogen.
3. Directions for use to provide not more than 20% of the additive in the total ration and a prominent statement: “Warning - This feed should be used only in accordance with the directions furnished on the label.” (Reg. 573.140; Proposed 1969, Adopted, 1970).

24.4 **Whole-Pressed Cottonseed, Mechanical Extracted** is composed of sound, mature, clean, delinted, and unhulled cottonseed, from which most of the oil has been removed by mechanical pressure. It must be designated and sold by its crude protein content. If ground, it must be so designated. The words “mechanical extracted” are not required when listing as an ingredient in a manufactured feed. (Proposed 1964, Adopted 1966, Amended 1968). IFN 5-01-609 Cotton seeds meal mechanical extracted.

24.51 **Low Gossypol Cottonseed Meal, Solvent Extracted** is a meal in which the gossypol is not more than 0.04% free gossypol. The words “solvent extracted” are not required when listing as an ingredient in a manufactured feed. (Proposed 1964, Adopted 1966, Amended 1968). IFN 5-01-633 Cotton seeds low gossypol meal solvent extracted.

24.6 **Cottonseed Hulls** consist primarily of the outer covering of the cottonseed. (Proposed 1964, Adopted 1966.). IFN 1-01-599 Cotton hulls.

24.8 **Cotton Plant By-Product** is the residue from the ginning of cotton. It consists of cotton burrs, leaves, stems, lint, immature seeds, and sand and/or dirt. It shall not contain more than 38% crude fiber, nor more than 15% ash. It must be labeled with minimum guarantees for crude protein and crude fat and maximum guarantees for crude fiber and ash. If it contains more than 15% ash, the words “sand and/or dirt” must appear in the product name. (Proposed 1980, Adopted 1983, Amended 1984). IFN 1-08-413 Cotton gin by-product.

Nutrient Composition of Cottonseed and By-products

Tables 1 and 2 outline the basic properties and the nutrient composition of cottonseed and the primary by-products derived from two oil-extraction processes. Calhoun et al. (1995b) conducted a large scale survey in cooperation with oilseed crushers to determine the relative nutrient content of cottonseed, cottonseed meal, and hulls that arise from the primary oil extraction processes used during the 1993-94 processing year. Before this study, the most comprehensive determination of nutritional values was conducted during the 1960s. Since then there have been significant changes in oil extraction technologies and periodic introductions of newer cotton varieties, which might have altered the nutrient composition of the various by-products being used today.

Generally, the survey revealed significant reductions in ether extract and higher fiber values for cottonseed since the 1960s. According to Calhoun et al. (1995b) these results were consistent with the downward trend in average seed index that has been observed during the past 18 years. Energy and protein values of cottonseed hulls were consistent with published values. Trace mineral elements were considerably different. Potassium was higher although sulfur, copper, iron, manganese and zinc were much lower in the collected samples compared to the published values.

The nutrient content of cottonseed meals varied depending on the process used to extract the oil. Compared to those produced 25 to 30 years ago, cottonseed meals produced today were shown to be higher in crude protein, magnesium, potassium, and sulfur, and lower in crude fiber, copper and manganese. Generally speaking, the major effect of extraction process on cottonseed meal is on fat content. As a rule, mechanically extracted cottonseed meals tend to have higher residual oil content than either pre-pressed solvent or solvent cottonseed meal. However, this may not always be the case because it is common practice to return refinery by-products (sodium salts of fatty acids) obtained during the refining process back into the meal stream immediately before the desolventizer-toaster process.

Table 1. Basic properties of cottonseed and cottonseed products.[a]

Product	Bulk density (lb/ft^3)	Bulk volume (ft^3/ton)	Weight (lb/bu)	Specific count (seed/lb)
Whole seed				
Loose on conveyor	20	100		
<24 ft. deep	25	80	32	1,800 - 2,400
24-50 ft. deep	27	75		
>50 ft. deep	30	70		
Machine delinted	35	57	44	2,400 - 3,200
Acid delinted	34-37	54	42-46	4,800 - 5,600
Meal (extracted)	38	53		
Hulls	12	167		
Pelleted Hulls	36	55		
Oil	57	35		

[a] Willcut et al., 1987

Table 2. Nutrient composition of cottonseed and by-products resulting from the cottonseed crushing process.[a]

Nutrient	Whole Cottonseed	Cottonseed Meal Expander Solvent Extracted NRC[a]	NCPA[b]	Cottonseed Hulls NRC[a]	NCPA[b]
Dry matter, %	92	91	89.1	91	89.9
Crude protein, %	23.0	45.2	47.6	4.1	5.0
NEm (Mcal/lb) [b]	1.10	.83		.31	
NEg (Mcal/lb) [b]	.76	.54		.07	
TDN, %	95	76		42	
Acid detergent fiber, %	20	17	17.3	64	67
Neutral detergent fiber, %	40		24.5	90	86.9
Crude fiber, %	20.8	13.3	11.2	47.8	48.6
Ether extract, %	17.50	1.6	2.2	1.7	1.9
Ash, %	5.0	7.1	7.5	2.8	2.8
Calcium, %.	16	.18	.22	.15	.15
Phosphorus, %	.75	1.21	1.20	.09	.08
Magnesium, %	.35	.59	.66	.14	.15
Potassium, %	1.21	1.52	1.72	.87	1.13
Sodium, %	.31	.05	.14	.02	.01
Sulfur, %	.26	.28	.44	.09	.05
Copper, ppm	54	22	12.5	13	3.6
Iron, ppm	151	228	126	131	30.1
Manganese, ppm	10	23	20.1	119	16.8
Molybdenum, ppm			2.5		.37
Zinc, ppm		68	63.7	22	9.9

[a] NRC = Nutrient Requirements of Beef Cattle, 6th ed., 1984.
NCPA = Calhoun, et al., 1995b.
[b] NEm and NEg = Net energy, maintenance and growth, respectively.

Feeding Value of Whole Cottonseed

Over the past 20 years, the percentage of whole cottonseed (WCS) fed directly to cattle has increased dramatically. Although its bulky physical form makes it a rather inconvenient feedstuff to handle, dairy producers have increasingly embraced the use of WCS as a source of energy, protein, and fiber in lactating dairy cow diets. Levels, as high as 25% of the ration, are fed with mostly positive results (Coppock and Wilks, 1991). Recent research has shown the benefits of feeding limited amounts of oilseeds (about 4% of total dry matter intake) to beef cows in marginal body condition before the breeding season (Williams and Stanko, 1997). For example, feeding about 3.5 pounds of WCS daily to a mature, 1,100 pound cow will help many cows begin cycling as early as possible.

Levels containing up to 50% whole cottonseed in the concentrate portion have been previously evaluated for beef cattle growing rations (Marion et al., 1976). After 68 days of receiving the diet, yearling cattle fed 50% WCS began scouring when they consumed 12 pounds of WCS per head daily. The concentration of whole cottonseed in the diet was reduced to 25%, then gradually increased to 40% by the end of the 112-day trial, and no further digestive disturbances were reported. Arizona research (Hale et al., 1983; Swingle et al., 1983) determined that increasing levels of WCS in beef cattle finishing diets resulted in a concomitant decrease in the energy utilization from WCS, and that a level of 20% showed a small advantage in cattle performance.

Lane, Jr. (2001) outlined the following guidelines for feeding cottonseed to beef cattle:

1. Feed only gin-run cottonseed. These are whole, non-delinted and untreated seed.
2. Feed only dry seeds that are not moldy.
3. Grinding whole fuzzy cottonseed does not improve feeding value.
4. Whole cottonseed should be hand-fed as it does not flow well through self-feeders. Cottonseed does not mix well with salt or other intake limiters.

To further elaborate on No. 2 above, WCS destined for livestock feeding should be clean, free of foreign debris, white to whitish-gray in color, and should rattle when shook. Storing cottonseed that is too wet at harvest may result in heating and/or molding which may predispose it to risks associated with aflatoxin and other mycotoxins. To minimize increases in aflatoxin during storage, Russell (1983) recommended storing seed at less than 10% moisture; forcing air through the seed; sheltering seed from rain; and storing seed on concrete that has a slight slope.

Gossypol Considerations

All cottonseed contains gossypol, a naturally occurring plant pigment found most commonly in cotton (Gossypium Spp.) and okra, as well as in most plants in the family Malvaceae. Gossypol is a polyphenolic compound that, in cotton, is localized in pigment glands found throughout the plant. These glands are especially concentrated in the seed. Cottonseed has been shown to contain from 0.40 to 2.0% free gossypol. The level of gossypol is affected by species, variety, fertilization, growing conditions, and insect pressure. The presence of gossypol affords the plant some protection against predators such as insects, field mice, and raccoons that might otherwise feed on these plants and/or their seeds (Boatner, 1948; Berardi and Goldblatt, 1969).

Gossypol exists as two stereoisomers, or mirror images of each other, which are designated as (+) and (-) isomers. The minus or “(-)” isomer has been shown to be more detrimental biologically within the animal. Upland cottonseed or “fuzzy cottonseed” usually contains less gossypol than PIMA varieties of cotton. PIMA seed also contains more (-) isomer as a percentage (50%) than Upland (40%). These isomers exist in two distinct states: bound and unbound. The unbound form of this compound has been shown to be most biologically active in the animal. The bound gossypol is essentially unavailable to the animal, (because these are chemical determinations) but the possibility for some crossover of biological activity exists (Calhoun et al., 1995a).

Whole cottonseed typically contains 1.5-2.0% gossypol, all in the unbound form, but levels can vary to as low as 0.4% in some commercial species. (Calhoun 1995a, Nomeir and Abou-Donia, 1985). Breakdown and maceration by chewing of this seed by the animal and subsequent exposure of this gossypol to rumen microorganisms allows a number of deactivation, binding, and degradation actions to occur that render the gossypol unavailable to the animal. Due to the nature of the rumen, prolonged exposure time, and extensive physical and chemical breakdown of the whole seed, the ruminant is given some practical protection from the compound. Binding to free epsilon amino nitrogen in the rumen – whether as free amino acids or peptides – attaching to microbial cell walls, or binding to available metal ions such as iron all contribute to the detoxifying action of the rumen.

Whole Cottonseed

Roasting, extruding, and cracking whole cottonseed has improved digestibility in some trials but also has increased the availability of free gossypol in several circumstances. This is especially true with PIMA seed because it has few linter fibers attached to lengthen residence time in the rumen. PIMA is generally ground to increase digestibility, but this exposes more of the glands to the rumen environment more quickly than with whole fuzzy cottonseed, decreasing the rumen's ability to render the gossypol unavailable to the animal (Kirk and Higginbotham, 1999). These processes also make the oil in the seed more readily available and can depress fiber digestion if not compensated for in the overall feeding of the ration.

Cottonseed Meal

Because of the process by which oil is extracted, cottonseed meal yields a predominately bound form of gossypol compared to whole cottonseed. After they are separated from the hull, the cottonseed meats are moistened, flaked and cooked before being put through an expander, extracted, and then desolventized and toasted (in another type of stacked heater called a DTDC) before being ground into a meal (Jones and King, 1996). This processing method binds much of the gossypol leaving only 0.1-0.2% as free gossypol. More than 97% of the meal from plants in the United States is made using this process (National Cottonseed Products Association, personal communication). This level of free gossypol is a decrease of nearly 50% from the 1960s and 1970s because of expander technology introduced to the oilseed industry. Surveys conducted by the National Cottonseed Products Association (NCPA) in the early 1990s and again in 2000 showed that the levels of free gossypol in meal manufactured with expander-solvent technology continue to remain low (< 0.18%, Forster and Calhoun, 1995b; Waldroup/NCPA survey data, 2000).

Cottonseed Hulls

Cottonseed hulls are removed from whole seed. The hull is mainly hemicellulose and lignin compounds with a nearly pure cellulose linter fiber attached (Tharp, 1948). No pigment glands have been reported on the hull fiber or linter fiber fractions. The residual oil and protein that may be present from the decortication or removal of the hull from the cottonseed meats may contain some free gossypol. Advances in mechanical and air separation techniques over the last 20 years have minimized the amount of residual oil and protein found in cottonseed hulls. This results in hulls typically reported as having less than 0.049 % free gossypol content (Forster and Calhoun, 1995). Pelleting hulls for transportation and convenient handling purposes can reduce this small free-gossypol level even further. Pelleted hulls have been shown to have the same feeding characteristics as loose hulls (Brown et al. 1977). Due to the low levels of gossypol found in hulls, gossypol poisoning from feeding hulls alone is not biologically possible.

Clinical signs of gossypol toxicity. Several manifestations of gossypol poisoning or gossypol toxicity are possible. No specific diagnostic test exists for determining gossypol toxicity because clinical signs are similar to other maladies. A history of cottonseed product consumption at above recommended levels, along with dyspnea, decreased growth rate, anorexia, weakness, and gastroenteritis are major indicators. Other signs have included abdominal distension and pulmonary edema. Clearly these symptoms indicate a number of disorders, and the intake of excess levels of gossypol should be the important factor. Plasma gossypol levels have been correlated with level of cottonseed product being fed. Most of the work has been done with dairy cattle. The underlying mode of action is that gossypol, which has not been rendered biologically inactive, passes into the bloodstream and is present in the plasma. Clinical signs of gossypol toxicity in mature cattle can include decreased dry matter intake, decreased milk production, panting, elevated heart rate, ruminal stasis, severe abomasitis, hemoglobinuria and sudden death. (Rogers and Poore, 1995). Decreased hematocrit and hemoglobin concentrations as well as increased erythrocyte fragility also have been linked with gossypol ingestion. The most frequently reported aspect of gossypol effects in beef cattle is on reproductive function in males. Long term or permanent reproduction in females has not been documented. Abnormal or reduced sperm motility in pubescent and growing bulls has been documented (Chase et al, 1989). When levels of whole cottonseed and cottonseed meal have been fed at levels that exceeded normal protein and energy supplementation levels, increased abnormal sperm and decreased normal motility have been seen. Mature bulls seem less susceptible than pubescent and adolescent bulls to gossypol toxicity (Chase et al, 1989). Even in cases where decreased normal sperm have been noted, the effects on herd conception rate have not been clear. Also, long-term effects on young bulls that have been fed excessive amounts of meal or whole seed have not been documented.

Gossypol analysis can be a difficult procedure with a number of compounds affecting the results. Analysis of pure samples of cottonseed products will give consistent results while analysis of mixed feeds can have errant values because a number of compounds can interfere with the Association of Official Analytical Chemists (AOCS) official method. High Performance Liquid Chromotography (HPLC) analysis is more accurate and can be carried out on mixed feeds with good success. Few commercial labs carry out gossypol analysis regularly.

Recommendations for Beef Cattle

These levels are based on the free gossypol intake in the total diet and are different for meal and whole cottonseed. Whole cottonseed has a higher feeding rate across production classes of beef cattle because it is digested slower and has a longer residence time in the rumen. These are taken from Rogers and Poore, 1995, Journal of Veterinary Medicine.

Nursing calves – preruminant calves should not be fed cottonseed products. Exposure can occur when nursing cow are supplemented whole seed or meal. Limits not to exceed 100 ppm free gossypol in the total diet.

Weaned heifer calves and stockers — Limit feeding or creep feeding calves supplements with cottonseed products until after the development of an active rumen. Whole cottonseed should not exceed 15% of the total diet. The limit for whole cottonseed is 900 ppm. Cottonseed meal should not contribute more than 200 ppm of free gossypol in the total ration.

Young bulls – should be limited to keep gossypol from meal below 150 ppm and from seed below 600 ppm. This is less than 3 pounds per day of a typical expander meal and less than 4 pounds of whole seed.

Mature bulls – keep ration below 200 ppm free gossypol from meal, especially during the breeding season.

Cows – Feeding less than 600 ppm from meal and less than 1,200 ppm from seed equates to 4 to 6 pounds per head from either source.

Feeding Value of Cottonseed Meal

Cottonseed meal (CSM) has been used successfully for more than 100 years in beef production in areas of the United States where cotton production and processing is prevalent. For example, CSM is used primarily as a protein source for a variety of beef production operations that include calf creeps and beef cow supplements.

After oil, cottonseed meal is the second most valuable and most abundant by-product of the crushing process (Figure 1). The nutrient analysis of CSM will depend on the process used to extract the cottonseed oil. The standard CSM is 41% crude protein on an as fed basis. The crude fiber level of CSM is significantly higher (13 vs. 5%) than that of soybean meal. Consequently, the protein and energy content of CSM is approximately 10 and 5%, lower respectively than soybean meal. According to Coppock (1987), the nutritional protein degradability of CSM is similar to that of peanut meal, canola meal, and soybean meal for lactating dairy cows, and to that of canola meal and soybean meal for young calves.

From an historical persepctive, when Oklahoma researchers (Hibberd et al., 1987) added increasing levels of CSM to low-quality native grass hay diets containing equal amounts of corn, they observed a significant improvement in digestibility. Several growth trials have supported these results through comparable performance using either hay-based (Brown, 1991) or silage-based (KSU, 1982) diets.

Several research trials with beef cows have estimated the protein and energy value of CSM, relative to other protein sources, under a variety of dietary conditions. A Louisiana study (Coombs, 1996) evaluated the effect of self-feeding supplements containing protein during late gestation and early lactation, or an energy supplement during the second half of the supplementation period, on cow weight change and subsequent calf performance. Cows had ad libitum access to a bermudagrass hay (9.9% crude protein and 49.6% TDN) throughout the supplementation period. The supplement treatments evaluated included CSM with salt (desired daily intake = 1.5 lb), a commercially available high protein (40%), and low protein (20%) block. Throughout the trial, there was no difference among supplement sources on cow weight change and weaning weights.

Using a low-quality native grass hay (4.7% crude protein) as the base diet, Gonzalez et al. (1988) supplemented fall-calving cows at calving with 2.5 lbs of CSM daily. During the first five weeks of lactation, the control treatment (no protein supplementation) lost more than 100 lbs of body weight, while the cows supplemented with CSM gained almost 50 lbs. Hay intake increased 33% for control cows and 110% for the CSM-supplemented cows during the first five weeks after calving. The supplemented cows produced more milk contributing to faster calf weight gain than control cows. This study illustrates that small quantities of CSM efficiently improved the utilization of low-quality forage and performance of lactating beef cows.

Florida researchers conducted two trials that evaluated the effects of supplemental CSM on the performance of nursing beef calves (Kunkle et al., 1991). The nursing calves averaged 430 to 560 lbs at the initiation of the two summer trials. Consumption of the CSM-salt supplement averaged 0.95 lb per head per day in trial 1 and 0.75 lb per head per day in trial 2. The calves creeped with CSM gained 0.45 lb per head per day more in trial 1 and 0.36 lb per head per day more in trial 2 compared to control cattle (Table 3).

Table 3. The effect of CSM used as a high protein creep on the performance of nursing calves[a]

	Trial 1			Trial 2		
	Control	**CSM**[b]	**SE**[c]	**Control**	**CSM**[b]	**SE**[c]
No. of calves	15	17		15	11	
Trial length, days	46	46		77	67	
Initial weight, lb	446	429	13	469	562	13
Final weight, lb	502	506	15	591	693	14
Calf daily gain, lb	1.20	1.65	.09	1.59	1.95	.11
Added gain, lb	—	.45		—	.39	
Supplement						
daily consumption						
lb/head/day	—	.95		—	.75[d]	
Lbs supplement						
per lb added gain	—	2.1		—	2.1	

[a] Kunkle et al., 1991.
[b] Cottonseed meal (100%) fed during the first 2 weeks then a mix of cottonseed meal-salt (92:8) fed to the end of the trial.
[c] SE = Standard error of mean.
[d] Rainwater contamination of feed caused molding. Consumption determined after subtracting estimated spoiled feed.

Feeding Value of Cottonseed Hulls

Cottonseed hulls (CSH) are a highly fibrous, bulky roughage. Nutrient values are given in Table 2. Unless they are pelleted or destined for use in a specific livestock market, such as in receiving diets, the low bulk density of CSH normally confines its use for livestock feeding applications to a fairly restricted market radius. Because of ease of handling, the use of pelleted CSH has increased in recent years (Coombs and Pontif, 1996). These factors, in addition to the variable oil crush and high storage costs, may cause CSH prices to be extremely volatile. Nevertheless, CSH are an important source of roughage and have been used successfully for several different beef feeding scenarios when dictated by economic conditions.

Several trials estimated the energy value of CSH relative to other roughage under a variety of diet conditions for beef cattle. Morrison (1948) reported CSH feed value was equivalent to 88 and 82% of prairie hay and unchopped peanut hay, respectively. Oklahoma researchers evaluated the influence of various types of forages on nutrient utilization with high roughage diets when fed with whole corn (Rust and Owens, 1982). The dietary inclusion level of all forages evaluated, including CSH was 50% with the remaining amount being 42% corn and 8% supplement. Their findings revealed that starch digestion was greatest for the CSH-supplemented diet, and that CSH may enhance the digestibility of whole corn, whereas others such as alfalfa may reduce digestion of whole corn. The CSH diet was 18% more digestible than expected while the alfalfa diet was 7% less. The results of this study agree with Teeter et al. (1981) whose work concluded that CSH fed at a high levels increased starch digestion by increasing rumination, reducing the amount of whole corn passing through the digestive tract.

Numerous university reports have indicated that CSH are a satisfactory source of roughage for beef cows, if the complete ration contains sufficient protein, minerals and vitamins. Morrison (1948) suggested that CSH should be fed with protein-rich feeds and as only part of the roughage, along with a good quality legume hay or silage. Arizona workers (Taylor et al., 1974) conducted a 116-day trial to compare various low-quality forages with beef cows nursing calves in a drylot setting. In one treatment, CSH constituted one-half (13.3 lb) of the experimental diet, which included ground alfalfa hay as the remaining ingredient. They concluded that the lactating cows fed the ration gained 40 lbs during the trial period. Furthermore, the calves from the CSH treatment gained 0.32 lb/day faster than the other two treatments (Treatment A = 21 lbs of ground alfalfa hay + 5 lbs pine sawdust and Treatment B = 20 lbs of ground milo stover + 4.5 lbs whole cottonseed) and consumed only 94 and 85% as much creep feed as calves assigned to treatments A and B, respectively. In a subsequent follow-up trial with dry, mid-gestation beef cows fed in a drylot setting, Taylor et al. (1977) concluded that CSH were superior to a Durum-type wheat straw.

Typically, feed intake of stressed, newly arrived feeder calves is low and extremely variable following transport and introduction into their new environment. Adequate energy intake is critical for mounting an effective immune response, and nutrition in the stressed animal plays a vital role in reducing susceptibility to disease. Consequently, rations fed during the receiving period must be palatable to encourage consumption and fortified with higher levels of protein, energy, minerals, and vitamins. Furthermore, the addition of a roughage source that is palatable and also an effective source of fiber, which promotes ruminal health, is critical throughout the calf's transition to a feedlot diet.

If prices permit, CSH are normally incorporated into commercial cattle receiving feeds. This has been observed by livestock producers and university researchers to assist in promoting feed consumption in newly arrived stocker calves. To quantify the value of CSH in a receiving diet relative to alfalfa hay, a study was conducted at Kansas State University to evaluate the growth performance and morbidity/mortality rates of 625 crossbred heifers in a 28-day receiving study (Blasi et al., 2001). Diets were formulated to contain either 40% of alfalfa hay or of a pellet containing 65% CSH and 35% CSM.

Heifers fed the cotton by-product pellet consumed more feed, but tended to be less efficient than the heifers that were fed alfalfa hay. Daily gains were comparable for heifers fed either diet. While the percentage of heifers diagnosed and treated (or re-treated) for respiratory disease were similar, percent mortality was numerically higher for those heifers fed the cotton by-product pellet (Table 4). Blending and pelleting CSH with CSM, reduces transportation and handling problems and enhances protein content.

Table 4. Performance of feeder heifers fed receiving diets containing alfalfa hay or cottonseed hulls (65%)/cottonseed meal (35%) pellets as sources of roughage.[a]

Item	Pelleted Cottonseed Hull/Meal[b]	Alfalfa Hay[b]	P=
Number of. Pens	12	12	
Number of. Heifers	313	312	
Daily Gain, lb/day			
Deads in basis	2.15	2.22	.83
Deads out basis	2.64	2.52	.72
Dry Matter Intake, lb/day	11.8	10.7	<.01
Feed:Gain			
Deads in basis	5.61	4.78	.27
Deads out basis	4.52	4.23	.54
Mortality	3.2	1.9	.38
Pulled, %	48.8	45.3	.44
Treated, %	35.7	35.2	.89
Retreated, %	26.2	23.2	.38

[a] Blasi et al., 2001.
[b] Contained 40% of a 65:35 CSH:CSM mixture or alfalfa hay; nutrient composition: 15% crude protein, 20% ADF, 0.49 calculated NEg (Mcal/lb).

In another trial conducted previously with alfalfa versus CSH for starting cattle on high concentrate rations, Gill and Owens (1982) fed rations to starting feedlot steers that were diluted with CSH or a mixture of CSH plus alfalfa meal for the first 24 days of a 119-day feeding period. No significant differences were detected in performance, although steers receiving alfalfa meal consumed an average of 1.4% more feed, which increased efficiency by 1.7%. So based upon the results of this study and the one previously discussed, pelleted cottonseed by-products (CSH and CSM) are comparable to alfalfa hay when fed in receiving diets and can be used successfully in areas of the United States. where alfalfa hay is priced at a premium.

Numerous university trials have evaluated CSH as a source of roughage for growing beef calves. During a 3-year period, Bagley et al. (1983) conducted a winter feeding study with a total of 150 head of 485 lb 10-month old replacement heifers. The study compared rations consisting of bermudagrass hay + 1 lb of CSM; CSH + 2 lb of CSM; CSH + 1.7 lb of CSM + 2.7 lb of corn; soybean straw + 2.8 lb of CSM; and, soybean straw + 1.5 lb of CSM + 2.7 lb of corn. All roughage sources were available on a free-choice basis, and diets were formulated to contain 12.5% crude protein. Heifers fed bermudagrass hay and CSM gained faster than did heifers fed CSM and either CSH or soybean straw (Table 5). Heifers fed CSH gained faster and were heavier ($P<.01$) than heifers fed soybean straw diets. Adding corn to both CSH and soybean straw diets increased final weights and daily gain.

Table 5. Roughage consumption and performance of beef heifers fed a roughage-based wintering diet.[a]

	Diet				
Item	**Bermuda-grass hay + CSM protein**[b]	**Cottonseed hulls+ CSM protein**	**Hulls + protein +energy**[c]	**Soybean straw + CSM protein**	**Straw + CSM protein + energy**
Dry matter consumption, lb/day	11.9	11.2	11.1	6.6	6.8
Initial weight, lb	484	484	485	487	483
Daily gain, lb	.68[e]	.44[f]	.77[e]	-.42[g]	.15[d]
Final condition score[i]	9.1[e,f]	7.9[f,g]	9.6[e]	4.5[h]	6.9[g]
Final weight, lb	541	521	550	451	496

[a] Bagley et al., 1983
[b] Cottonseed meal (41 percent crude protein)
[c] Ground yellow corn
[d,e,f,g,h] Means in the same row followed by different letters (P<.05).
[i] Visual rating of condition, 18-point scale: 4 = average utility; 6 = low standard; 9 = low good; 18 = high prime.

Table 6. Summary of Feedlot Performance.[a]

	Ration				
Performance Item	**Basal**	**Hulls**	**Hulls, urea**	**Hulls, soybean meal**	**Hulls soybean meal, and minerals**
CSH Level in Diet As Fed, %	0	10	9	10	7
Initial 83 days					
Starting weight, lb	425	427	424	424	425
Weight at 83 days, lb	623	664	638	654	620
Daily gain, lb	2.3	2.8	2.6	2.7	2.3
Feed consumed, lb/day	17.7	19.9	19.0	18.6	17.0
Feed/Gain	7.7	7.1	7.3	6.9	7.4
Entire 236 days					
Final weight, lb	929	977	960	978	944
Daily gain, lb	2.1	2.3	2.3	2.3	2.2
Feed consumed, lb/day	21.0	22.3	22.1	21.4	20.9
Feed/Gain	10.0	9.7	9.6	9.3	9.5

[a] Thomas et al., 1985.

Thomas et al., (1985) conducted a 236-day growing trial with 425 lb heifers to evaluate adding CSH, CSH + urea, or a combination of CSH + SBM, to a basal diet consisting of 57% ground corn and 43% broiler litter. All diets were calculated to contain equal amounts of energy and protein. On average, addition of roughage as CSH improved feed efficiency by 6.8% over the basal diet, and the CSH-soybean meal diet improved feed efficiency by 10.3% (Table 6). Feed intake increased an average of 5.2% when CSH were added to the basal diet. This may largely account for the improved efficiency for the CSH-supplemented diets.

These researchers concluded that the addition of CSH to the basal diet resulted in faster gains, more feed consumed with a resulting improvement in feed efficiency.

References

Association of American Feed Control Officials. 2001. Official Publication. Atlanta, GA.

Bagley, C.P., J.I. Feazel and J.C. Carpenter. 1983. Soybean straw and cottonseed hulls for wintering beef heifers. Louisiana Ag. 27:10.

Berardi, Leah C. and Leo A. Goldblatt. 1969. Chapter 8. Gossypol. In: Toxic Constituents of Plant Foodstuffs. Academic Press Inc. New York.

Blasi, D.A., J.S. Drouillard, T.B. Farran, R.D. Hunter, S.P. Montgomery and J.J. Sindt. 2001. Using a mixture of cottonseed hulls and cottonseed meal to replace alfalfa hay in diets for stressed feeder calves. In: Cattlemen's Day, Kansas State Univ. Res. and Ext. Rep. Prog. 873, 95.

Boatner, Charlotte H. 1948. Chapter VI. Pigments of Cottonseed. In: Cottonseed and Cottonseed Products - Their chemistry and chemical technology. Alton E. Bailey Ed. Interscience Publishers, Inc. New York.

Brown, W.F. 1991. Molasses and cottonseed meal supplementation of ammoniated hay for yearling cattle. In: Florida Beef Cattle Res. Rep. p. 63.

Brown, W.H., F.M. Whiting, B.S. Daboll, R.J. Turner, and J.D. Schuh. 1977. Pelleted and nonpelleted cottonseed hulls for dairy cows. J. of Dairy Science. 60:919.

Calhoun, M.C., S.W. Kuhlmann and B. C. Baldwin Jr. 1995a. Assessing the Gossypol Status of Cattle fed Cotton Feed Products. Proceedings Pacific Northwest Nutrition Conference. October 11, 1995.

Calhoun, M.C., S.W. Kuhlmann and B.C. Baldwin. 1995b. Cotton feed product composition and gossypol availability and toxicity. 2nd Nat. Alternative Feeds Symp., St. Louis, MO. Ed. M.L. Eastridge. p. 125.

Chase, C.C. Jr., P. Bastidas, J. L. Ruttle, C. R. Long, and R.D. Randel. 1994. Growth and Reproductive Development in Brahman Bulls Fed Diets Containing Gossypol. J. Anim Sci 72:445.

Coombs, D.F. and J.E. Pontif. 1996. An evaluation of cottonseed hulls and cottonseed hull pellets in beef cattle diets. Ann. Res. Sum., Dean Lee Res. Stat., LAES, p. 3.

Coombs, D.F. and D.W. Sanson. 1999. Winter supplementation of spring-calving beef cows. In: Beef Cattle Res. Rep. 30:29.

Coppock, C.E. 1987. Supplying the energy and fiber needs from alternate feed sources. J. of Dairy Sci. 70:1110.

Coppock, C.E. and D.L. Wilks. 1991. Feeding whole cottonseed and cottonseed meal to dairy and beef cattle. 2nd Nat. Alternative Feeds Symp., St. Louis, MO. Ed. M.L. Eastridge. p. 43.

Davis, Jr., G.V.1982. Cottonseed meal, soybean meal, and dehydrated alfalfa for steers fed corn-silage growing rations. In: Cattle Feeders' Day, Kansas State Univ. Rep. of Prog. 416. p. 22.

Forster, L. A., Jr. and M. C. Calhoun. 1995. Nutrient values for cottonseed products deserve a new look. Feedstuffs 67(44):16.

Gill, D.R. and F.N. Owens. 1982. Alfalfa vs cottonseed hulls for starting cattle on high concentrate rations. In: Anim. Sci. Res. Rep., Okla. State Univ. MP-112, p. 138.

Gonzalez, J.M., C.A. Hibberd, R.R. Scott and B.D. Trautman. 1988. Digestive and metabolic changes in fall-calving beef cows due to stage of production and early postpartum protein supplementation. In: Anim. Sci. Res. Rep., Okla. State Univ. MP-125, p. 76.

Hale, W.H., F. Prouty, A. Urias, R.S. Swingle, J.A. Marchello, C.B. Theurer and S. Felix. 1983. Evaluation of various levels of whole cottonseed in finishing diets for yearling steers. Arizona Cattle Feeders' Day, p. 11.

Hibberd, C.A., C.C. Chase, Jr., and L.D. Bourquin. 1987. Added cottonseed meal for beef heifers consuming corn-supplemented low-quality native grass hay diets. In: Anim. Sci. Res. Rep., Okla. State Univ. MP-119, p. 275.

Jones, L. and C. King. 1996. Chapter 4. Cottonseed Oil. In: Baileys Industrial Oil and Fat Products. Volume 2, Edible Oil and Fat Products: Oils and Oilseeds. Y.H. Hui, Ed. J.W. Wiley and Sons Inc. New York.

Kirk, John H. and Gerald E. Higginbotham. 1999. PIMA Cotton, Gossypol and Dairy Cattle- Is It A Bad Combination? Western Dairyman. August.

Kunkle, W.E., P. Hogue and S. Sumner. 1991. Effect of a cottonseed meal supplement on the performance of nursing calves. In: Florida Beef Cattle Res. Rep. p. 79.

Lane, Jr., C.D. 2001. Feeding cottonseed and cotton by-products to beef cattle. Univ. of Tenn. Knoxville. http://www.utextension.utk.edu/ansci

Leahy, J. 1948. Chapter III. Structure of the Cottonseed. In: Cottonseed and Cottonseed Products - Their chemistry and chemical technology. Alton E. Bailey, Ed. Interscience Publishers, Inc. New York.

Marion, P.T., J.L. Arnold and J.K. Riggs. 1976. Whole cottonseed fed at high levels to finishing beef cattle. Beef Cattle Res. in Texas. 1974-75. Consol. PR-3383C.

Morrison, F.B. 1948. Feeds and Feeding, 21st Ed. The Morrison Publishing Co. Clinton, IA.

National Cottonseed Products Association. 2001. Cotton: America’s True Food & Fiber Crop. http://www.cottonseed.com/about2.htm Memphis, TN.

Nomeir, A.A. and M.B. Abou-Donia. 1985. Chapter 9. Toxicological Effects of Gossypol. In: Male Fertility and Its Regulation. T.J. Lobl and E.S. E. Hafez, Eds. MTP Press Limited. Boston, MA.

NRC. 1984. Nutrient requirements of beef cattle. 6th ed. National Academy Press, Washington, DC.

Rogers, Glenn M. and Matthew H. Poore. 1995. Optimal Feeding Management of Gossypol- Containing Diets for Beef Cattle. J. of Vet. Med. p. 994.

Russell, T.E. 1983. Aflatoxins and the storage of whole fuzzy cottonseed. Arizona Dairy Newsletter. Feb. p. 2.

Rust, S.R. and F.N. Owens. 1982. Forage sources with whole corn in receiving diets for cattle. In: Anim. Sci. Res. Rep., Okla. State Univ MP-112, p. 201.

Swingle, R.S., P.G. Daniels, W.H. Hale and J.D. Schuh. 1983. Energy values for whole cottonseed in high concentrate feedlot diets. In: Univ. Arizona Cattle Feeders’ Day, p. 3.

Taylor, B.R., M. Belew, G. Barney, S. Swingle and M. Selke. 1974. Drylot cow-calf research: Low quality roughage for cows nursing calves. Univ. Arizona Cattle Feeder’s Day. P-33, p. 3.

Taylor, B.R., M. Selke and W.H. Hale. 1977. Drylot cow-calf research: Utilization of low quality roughage in maintaining beef cows. In: Univ. Arizona Cattle Feeder’s Day. P-36, p. 12.

Teeter, R.G., F.N. Owens and D.R. Gill.1981.Roughage-concentrate associative effects. In: Anim. Sci. Res. Rep., Okla. State Univ. MP-108, p. 161.

Tharp, W. H. 1948. Chapter IV. Cottonseed Composition — Relation to Variety, Maturity and Environment of the Plant. In: Cottonseed and Cottonseed Products — their chemistry and chemical technology. Alton E. Bailey, Ed. Interscience Publishers, Inc. New York.

Thomas, E.E. and G.W. Turnbull and J.T. Eason. 1985. Cottonseed hulls improve feed efficiency and gain of cattle on broiler litter diets. In: Highlights of Agric. Res., Auburn Univ. 32:10.

United States Department of Agriculture. 2000a. U.S. cotton production by state. Crop Production.

United States Department of Agriculture. 2000b. Cottonseed: supply & disappearance. Oil Crops Outlook and Situation Report.

Waldroup, P. 2000. NCPA Oil Mill Industry Survey . 1999 Data collection. National Cottonseed Products Association. Summary, Industry Data. NCPA Technical Files.

Williams, G.L. and R.L. Stanko. 1997. Dietary fat supplementation enhances reproductive performance in cattle: Fact or fiction? Liquid Feed Symp. Proc. St. Louis, MO. p. 49.

Willcut, M. H. W.D. Mayfield and T.D. Valco. 1987. Cottonseed storage. Cotton Inc. http://www.cottoninc.com/CottonSeed.

Authors

Dale A. Blasi
Professor
Beef Forage, Nutrition and Management
Animal Sciences and Industry
Kansas State University

Jim Drouillard
Professor
Feedlot Nutrition
Animal Sciences and Industry
Kansas State University

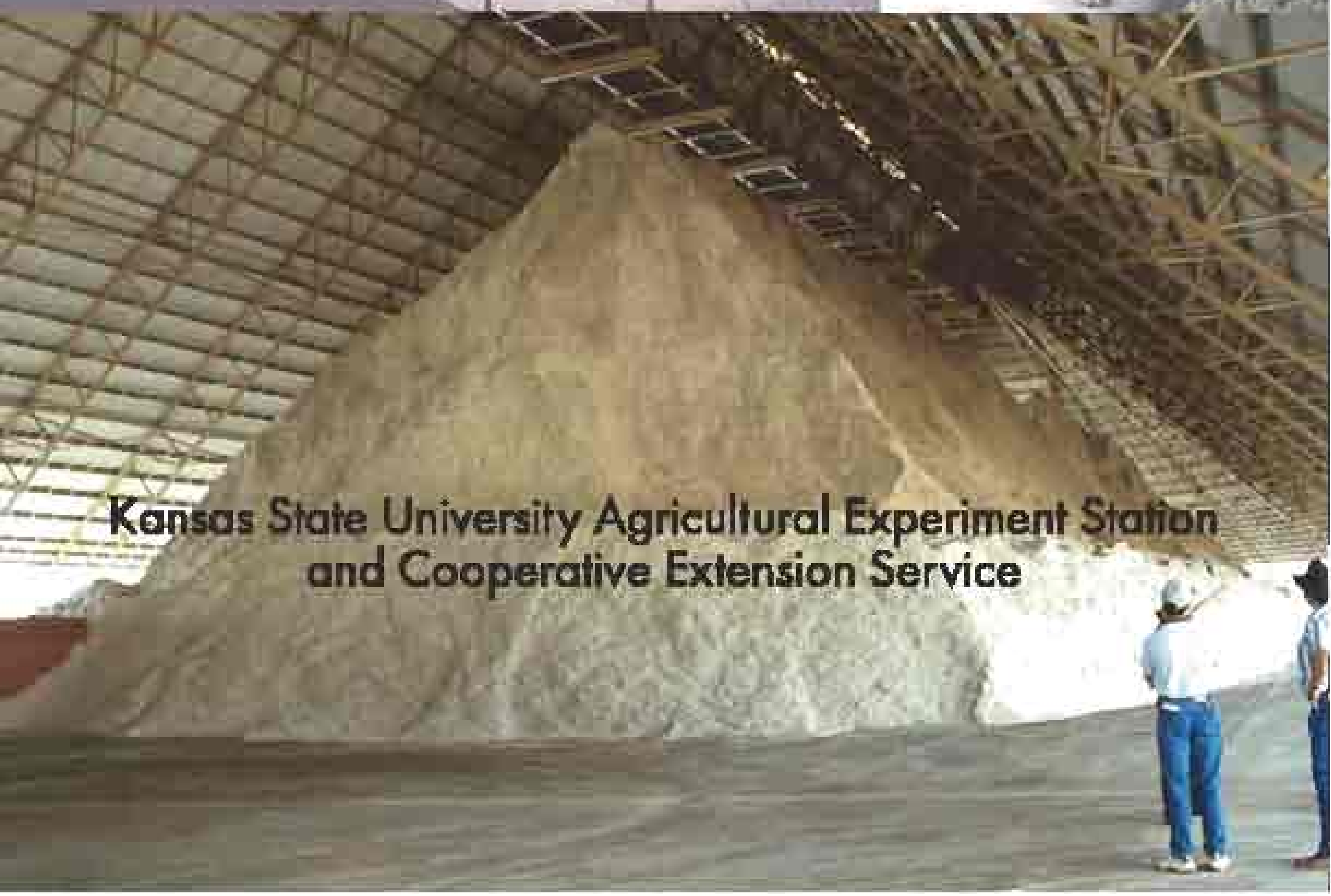
Special thanks to Lance A. Forster Jr., Ph.D., a nutritionist with Archer Daniels Midland Co., Decatur, Ill., for his insights and suggestions in the development of this manuscript.

Contribution No. 02-426-E from the Kansas Agricultural Experiment Station

Publications from Kansas State University are available on the World Wide Web at: http://www.oznet.ksu.edu

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF-2538 May 2002

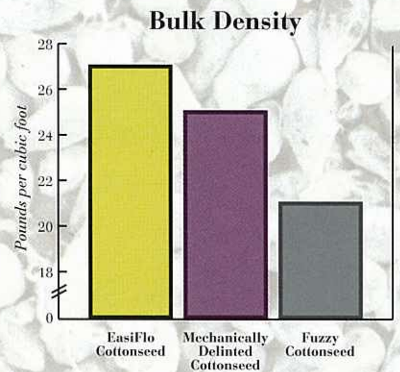


Kansas State University Agricultural Experiment Station
and Cooperative Extension Service

Appendix C - Easiflo Cottonseed Brochure

can simply be augered, which greatly reduces handling time and labor costs.

Additionally, EasiFlo cottonseed has storage advantages. The new coated seed has a greater bulk density than other cottonseed products. While fuzzy cottonseed and mechanically delinted cottonseed weigh 21 and 25 pounds per cubic foot, respectively,



University of Wisconsin research shows bulk density of cottonseed products.

EasiFlo cottonseed weighs 27 pounds per cubic foot. This allows feed companies and dairy producers to store up to 25 percent more EasiFlo cottonseed in the same amount of space originally used for fuzzy cottonseed.

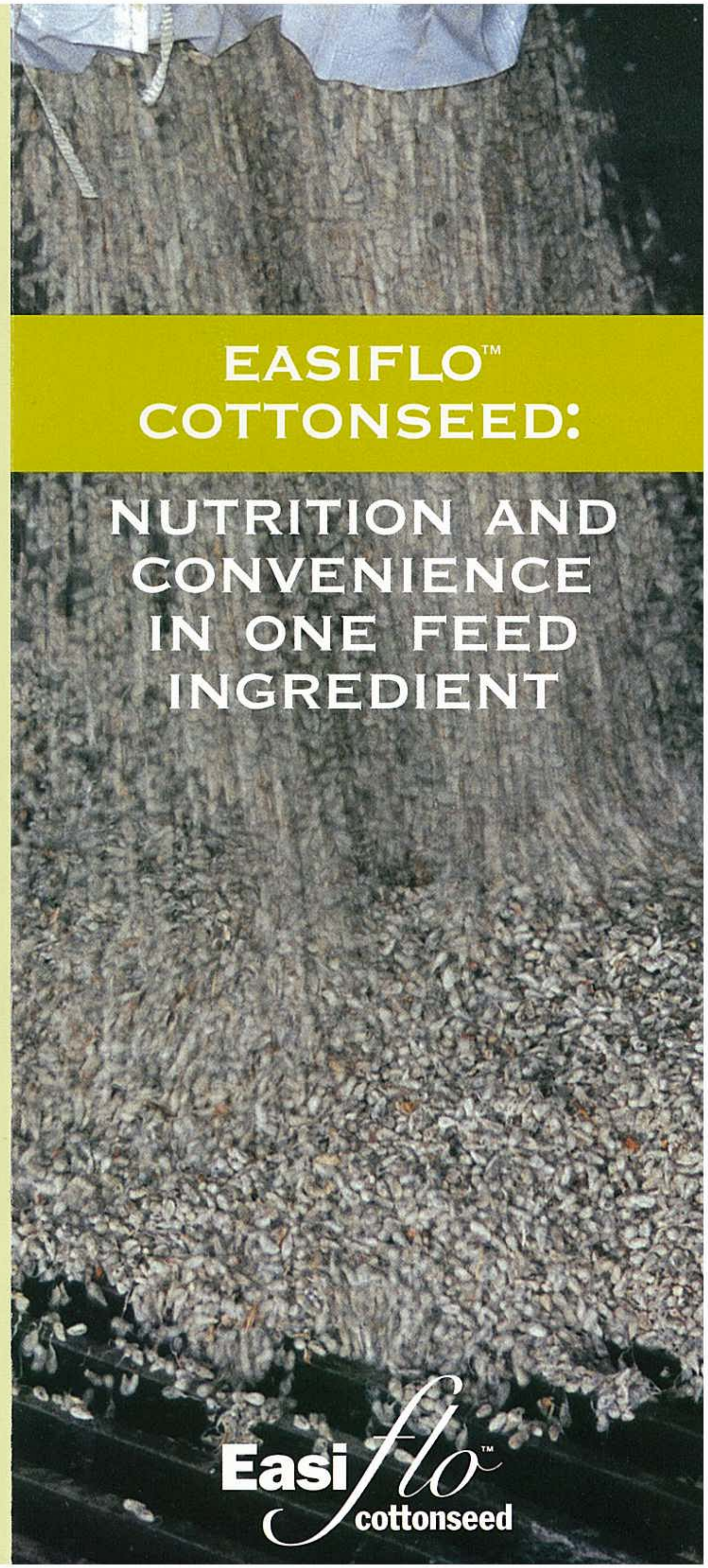
This density advantage also lowers shipping costs because greater amounts of EasiFlo cottonseed can be transported at once. The greater density saves EasiFlo cottonseed users about $20 a ton over fuzzy cottonseed on every 1,000 miles of freight. Plus, EasiFlo cottonseed can be moved in hopper-bottom trucks and rail cars versus the more expensive live bottoms.

EasiFlo Cottonseed is Ideal.

EasiFlo cottonseed has made a good product even better. With its all-in-one source of essential nutrients and easy handling characteristics, EasiFlo cottonseed is ideal for mills that are currently unable to handle fuzzy cottonseed. To find out more about EasiFlo cottonseed, contact Tom Wedegaertner, Director of Cottonseed Research and Marketing for Cotton Incorporated, at (919) 678-2369 or e-mail at twedegaertner@cottoninc.com.

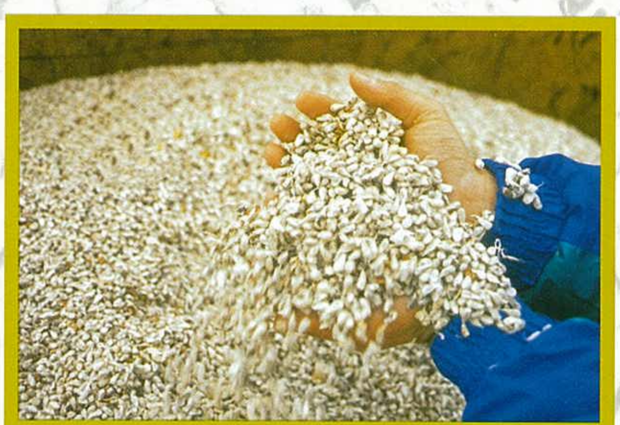
Cotton Incorporated
6399 Weston Parkway
Cary, NC 27513
http://www.cottoninc.com

EasiFlo cottonseed



A Revolutionary New Feed Ingredient. Cotton Incorporated has developed a new cottonseed product that will completely change the feed industry. EasiFlo™ cottonseed has the same nutritional benefits as fuzzy cottonseed, but is starch-coated to dramatically improve handling. This new cottonseed flows freely and can easily be augered through traditional grain handling equipment.

Research in Ohio, Mississippi, and Tennessee shows EasiFlo cottonseed contains the same all-in-one source of protein, fiber and fat found in fuzzy cottonseed, but offers a slight advantage over the traditional seed in the area of dry matter intake and feed utilization. EasiFlo cottonseed can help boost milk production when added to the rations of lactating dairy cows. And, EasiFlo cottonseed can be fed at the same rate as fuzzy cottonseed – 5 to 8 pounds per cow per day.



Developing EasiFlo Cottonseed. Some in the feed industry have been reluctant to fully utilize fuzzy cottonseed because of its challenging handling characteristics. The feedstuff can clump together and clog milling equipment, which can impact on labor and management costs. These facts prompted Cotton Incorporated to find a solution: a unique coated cottonseed that eliminates the flowability problem. A patented coating process seals cottonseed lint with a light paste of water and feed-grade starch, which keeps the seed from sticking together.

The U.S. Department of Agriculture's Cotton Ginning Research Laboratory in Lubbock, Texas, served as the pilot plant for EasiFlo cottonseed because of its proximity to the Cotton Belt. The lab's belt conveyor dryer plays an essential role in EasiFlo cottonseed production. After the cottonseed is coated, it moves along the rapid belt conveyor dryer to ensure that water does not penetrate the seed.

EasiFlo cottonseed flawlessly falls off the conveyor as it completes the coating process.

Easy to Handle and Store. Not only does EasiFlo cottonseed boast flowability benefits, but it has several other advantages over fuzzy cottonseed as well, including:

- Convenient handling
- Easy transportation
- Economical storage

EasiFlo cottonseed can be handled much more efficiently and effectively than fuzzy cottonseed. Fuzzy cottonseed is generally moved with a bucket loader and a live-bottom truck. EasiFlo cottonseed, however,

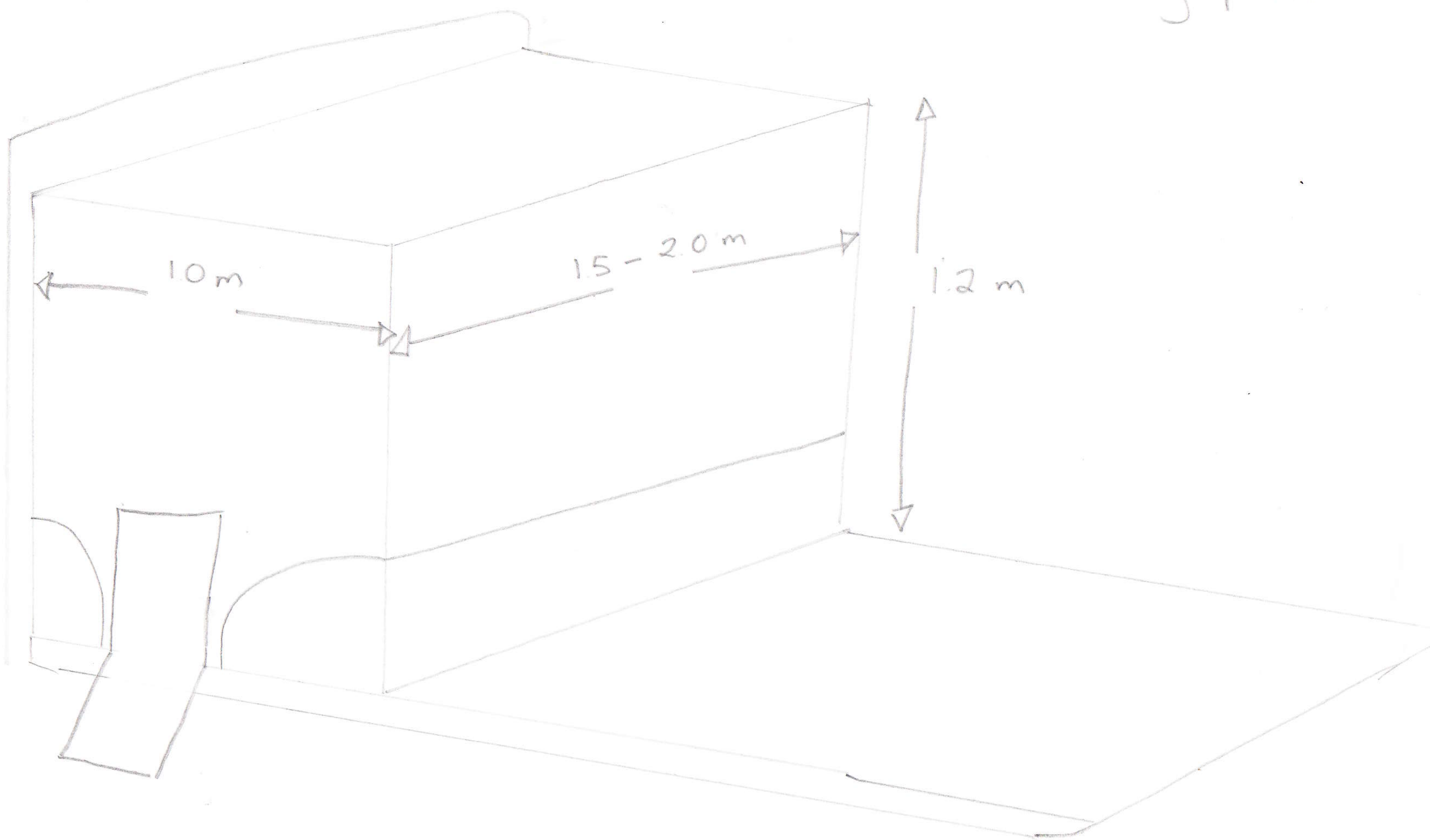
Appendix D - Initial Conceptual Sketch (Isometric View)

DAMIEN WOOLDRIDGE

Initial Conceptual Sketches

NOTE: Orientation is optional but preferable due to the ease of monitoring operation

These initial dimension give a rough capacity of 500kg of feed. From research this should cater to a small scale operation. Testing will take place on this pototype before larger/smaller scale systems are created



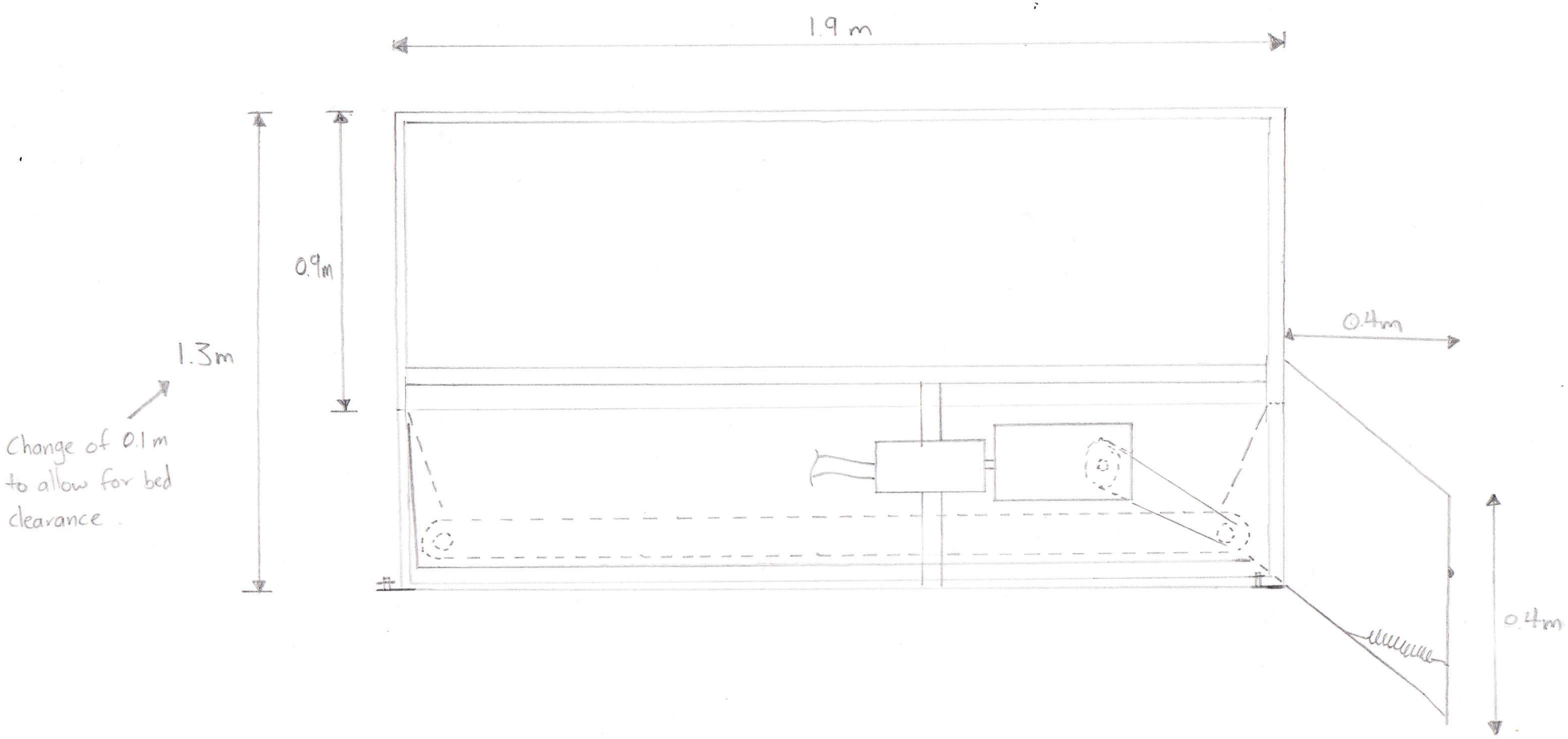
Initial Geometry and General Dimensions

Appendix E - Initial Orientation Sketch (Front/Rear View)

DAMIEN WOOLDRIDGE

Initial Orientation Sketch

Front/Rear View



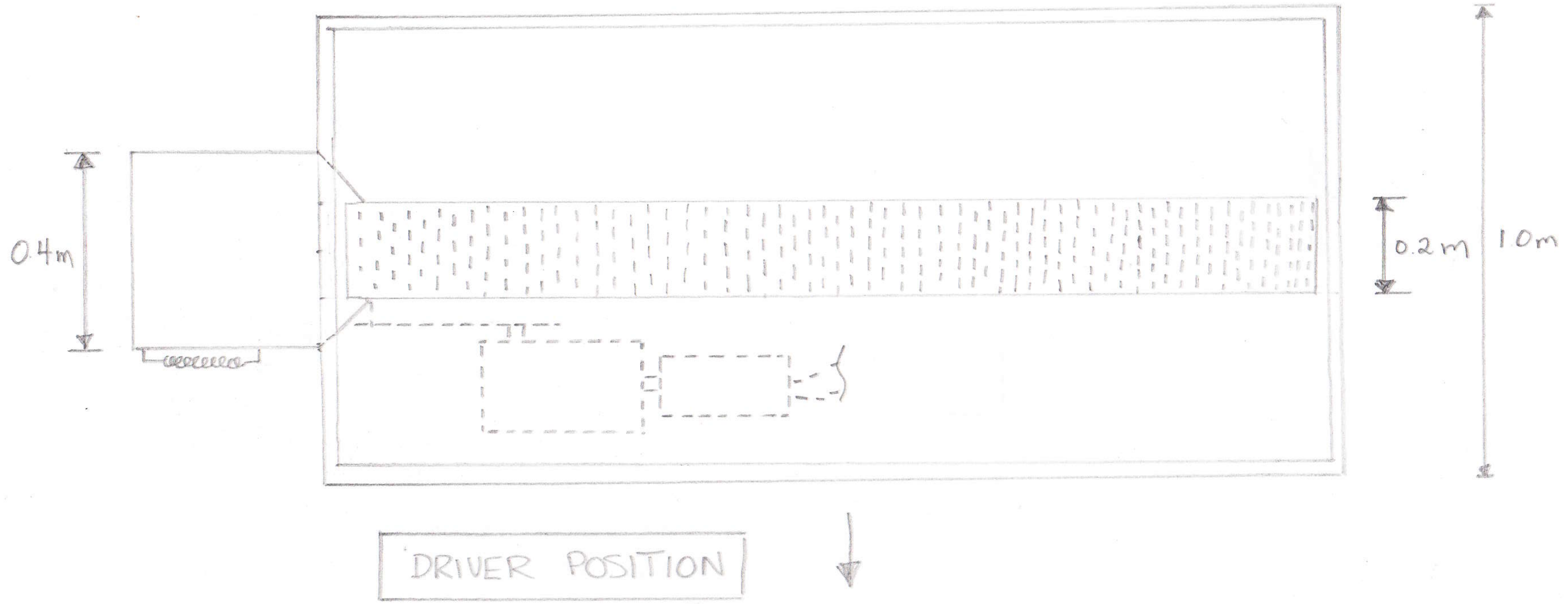
NOTE: The above sketch shows the front view of the system. This gives an initial idea of orientation for the drive system and the trap door dispenser. The conveyor system can be seen on the floor and the exterior frame built from RHS can be seen. Minor dimensional changes have been made after calculations of storage and the need for clearance.

Appendix F - Initial Orientation Sketch (Top View)

DAMIEN WOOLDRIDGE

Initial Orientation Sketch

Top View

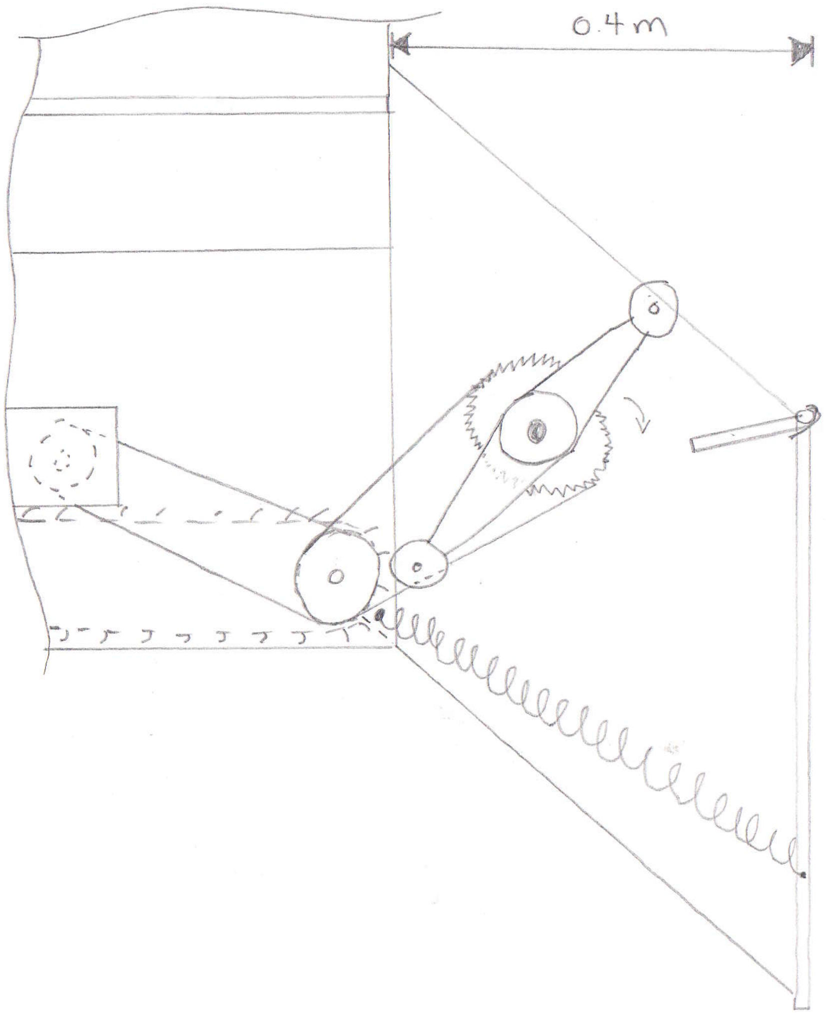


NOTE: The conveyor width seemed illogical at 0.3m so was reduced to more appropriate width. This also increased the cost effectiveness of the system. Drive system can be attached either against cabin or in orientation shown above. For ease of operation and monitoring the drive system should be placed as shown above. Even when system is rotated for American application the system will be seen for opposite side of tray for monitoring.

Appendix G - Trap Door Dispenser Unit Initial Concept

DAMIEN WOOLDRIDGE

Trap Door Dispenser Unit
Initial Concept



NOTE: This initial concept for triggering the door to empty the chamber will be a simple arm device driven by the main conveyor axle. The previous top view of the device did not display this system and the main axle will need to extended to create a straight line to the gear. By approqpriate reduction of gears the arm movement can be adjusted to the needed drop rate depending on the conveyor speed

Appendix H - Orrcon Steel Precision Sheet Brochure

PLAIN PLATE

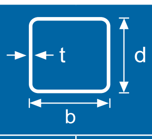
Section: Steel Sheet Coated & Uncoated
Standard: AS/NZS 1365, 1397, 1594, 1595
Surface Finish: Mill Finish, GALVABOND®, ZINCANNEAL®, ZINCALUME®, COLORBOND®

Thickness		Sheet Size mm x mm	Sheet Count / Tonne			
Hot Rolled	Cold Rolled		Hot Rolled	GALVABOND®	ZINCANNEAL® ZINCALUME®	Sign White & COLORBOND®
	0.40	1800 x 1200		132.76		
	0.40	2400 x 1200		99.57		
	0.55	1800 x 1200		100.48	102.38	100.20
	0.55	2400 x 1200		75.36	76.78	75.16
	0.75	1800 x 1200		74.95	75.67	
	0.75	2400 x 1200		56.21	56.75	
	0.95	1800 x 1200		59.76	61.01	
	0.95	2400 x 1200		44.82	45.76	
	1.15	1800 x 1200		49.69	50.55	
	1.15	2400 x 1200		37.27	37.91	
	1.15	2400 x 1500			30.77	
1.60	1.55	1800 x 1200	38.86	37.16	37.65	
1.60	1.55	2400 x 1200	27.64	27.87	28.33	
1.60	1.55	3000 x 1200	22.12	22.30	22.59	
	1.55	3000 x 1500		18.26		
2.00	1.95	1800 x 1200	29.49	29.68	29.99	
2.00	1.95	2400 x 1200	22.12	22.26	22.49	
2.00	1.95	3000 x 1200	17.69	17.81	17.99	
2.50	2.45	1800 x 1200	23.59	23.80		
2.50	2.45	2400 x 1200	17.69	17.85		
2.50	2.45	3000 x 1200	14.15	14.28		
3.00	2.95	1800 x 1200	19.66	19.75		
3.00	2.95	2400 x 1200	14.74	14.82		
3.00	2.95	3000 x 1200	11.80			

NOTE
- GALVABOND®, ZINCANNEAL®, ZINCALUME®, COLORBOND® **are all registered trade names of Bluescope Steel.**

Appendix I - Orrcon Steel Structural SHS Brochure

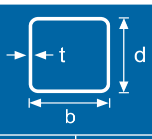
STRUCTURAL SQUARE (SHS)



Section: Square (SHS)
Standard - Grade: AS/NZS1163 - C350L0
Surface Finish: PTD / ALLGAL / OILED / NOPC

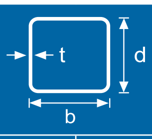
Size dxb (mm)	Nom. Thick (mm)	Surface Finish		Nom. Linear Mass (Kg/m)	Nom. Mtre/ Tonne	Lengths / Pack	Lengths / MiniPak
		PTD	ALLGAL				
6500mm Length							
20x20	1.6	✓	✓	0.87	1146	100	49
25x25	1.6	✓	✓	1.12	890	100	49
25x25	2.0	✓	✓	1.36	733	100	49
25x25	2.5	✓	✓	1.64	610	100	49
25x25	3.0	✓	✓	1.89	529	100	49
8000mm Length							
30x30	1.6	✓	✓	1.38	727	100	49
30x30	2.0	✓	✓	1.68	596	100	49
30x30	2.5	✓	✓	2.03	492	100	49
30x30	3.0	✓	✓	2.36	423	64	36
35x35	1.6	✓	✓	1.63	615	100	49
35x35	2.0	✓	✓	1.99	502	100	49
35x35	2.5	✓	✓	2.42	412	64	30
35x35	3.0	✓	✓	2.83	353	64	30
40x40	1.6	✓	✓	1.88	533	81	36
40x40	2.0	✓	✓	2.31	434	81	36
40x40	2.5	✓	✓	2.82	355	64	30
40x40	3.0	✓	✓	3.30	303	64	30
40x40	4.0	✓	✓	4.09	244	49	25
50x50	1.6	✓	✓	2.38	420	64	30
50x50	2.0	✓	✓	2.93	341	64	30
50x50	2.5	✓	✓	3.60	278	49	25
50x50	3.0	✓	✓	4.25	236	49	25
50x50	4.0	✓	✓	5.35	187	36	20
50x50	5.0	✓	✓	6.39	156	30	16
50x50	6.0	✓		7.32	137	25	12
65x65	1.6	✓	✓	3.13	319	49	25
65x65	2.0	✓	✓	3.88	258	42	20
65x65	2.5	✓	✓	4.78	209	42	20
65x65	3.0	✓	✓	5.66	177	36	20
65x65	4.0	✓	✓	7.23	138	30	16
65x65	5.0	✓	✓	8.75	114	25	12
65x65	6.0	✓		10.15	99	20	12

STRUCTURAL SQUARE (SHS)



Section: Square (SHS)
Standard - Grade: AS/NZS1163 - C350L0
Surface Finish: PTD / ALLGAL / OILED / NOPC

Size dxb (mm)	Nom. Thick (mm)	Surface Finish PTD	Surface Finish ALLGAL	Nom. Linear Mass (Kg/m)	Nom. Mtre/ Tonne	Lengths / Pack	Lengths / MiniPak
8000mm Length							
75x75	2.0	✓	✓	4.50	222	30	16
75x75	2.5	✓	✓	5.56	180	30	16
75x75	3.0	✓	✓	6.60	152	30	16
75x75	3.5	✓	✓	7.53	133	25	12
75x75	4.0	✓	✓	8.49	118	25	12
75x75	5.0	✓	✓	10.32	97	20	9
75x75	6.0	✓		12.03	83	16	9
89x89	2.0	✓	✓	5.38	186	25	9
89x89	2.5	✓	✓	6.66	150	20	9
89x89	3.5	✓	✓	9.07	110	20	9
89x89	5.0	✓	✓	12.51	80	16	9
89x89	6.0	✓		14.67	68	12	6
100x100	2.0	✓	✓	6.07	165	20	12
100x100	2.5	✓	✓	7.53	133	20	9
100x100	3.0	✓	✓	8.96	112	20	9
100x100	4.0	✓	✓	11.63	86	12	9
100x100	5.0	✓	✓	14.24	70	12	6
100x100	6.0	✓		16.74	60	12	6
100x100	9.0	✓		23.50	43	9	



Section: Square (SHS)
Standard - Grade: AS/NZS1163 - C350L0
Surface Finish: PTD / ALLGAL / OILED / NOPC

Size dxb (mm)	Nom. Thick (mm)	Surface Finish PTD	Surface Finish ALLGAL	Nom. Linear Mass (Kg/m)	Nom. Mtre/ Tonne	Lengths / Pack 8000mm	Lengths / Pack 12000mm	Lengths / MiniPak 8000 & 12000mm
8000mm & 12000mm Length								
125x125	4.0	✓	✓	14.80	68	9	9	6
125x125	5.0	✓	✓	18.17	55	9	9	6
125x125	6.0	✓		21.45	47	9	9	4
125x125	9.0	✓		30.60	33	8	4	
150x150	5.0	✓		22.10	45	9	6	
150x150	6.0	✓		26.20	38	6	6	
150x150	9.0	✓		37.70	27	6	4	
200x200	5.0	✓		29.90	33	6	4	
200x200	6.0	✓		35.60	28	4	4	
200x200	9.0	✓		51.80	19	4	2	
200x200	12.5	✓		69.40	14	2	2	
200x200	16.0	✓		85.50	12	1	1	
250x250	6.0	✓		45.00	22	4	2	
250x250	9.0	✓		65.90	15	2	2	
250x250	12.5	✓		89.00	11		1	
250x250	16.0	✓		111.00	9		1	
300x300	6.0	✓		54.42	18	1	1	
300x300	9.0	✓		80.05	12		1	
300x300	12.5	✓		109.00	9		1	
300x300	16.0	✓		136.00	7		1	
350x350	9.0	✓		94.18	11		1	
350x350	12.5	✓		128.00	8		1	
350x350	16.0	✓		161.00	6		1	
400x400	9.0	✓		108.31	9		1	
400x400	12.5	✓		148.00	7		1	
400x400	16.0	✓		186.00	5		1	

NOTE:
* Non standard sizes, surface finish and lengths available, subject to enquiry. Minimum order quantities (MOQ) apply.
* C450L0 grade available for some sizes, subject to enquiry. Minimum order quantities (MOQ) apply.
* NOPC & OILED available upon enquiry.

Appendix J - Prototype Skeleton Isometric Views

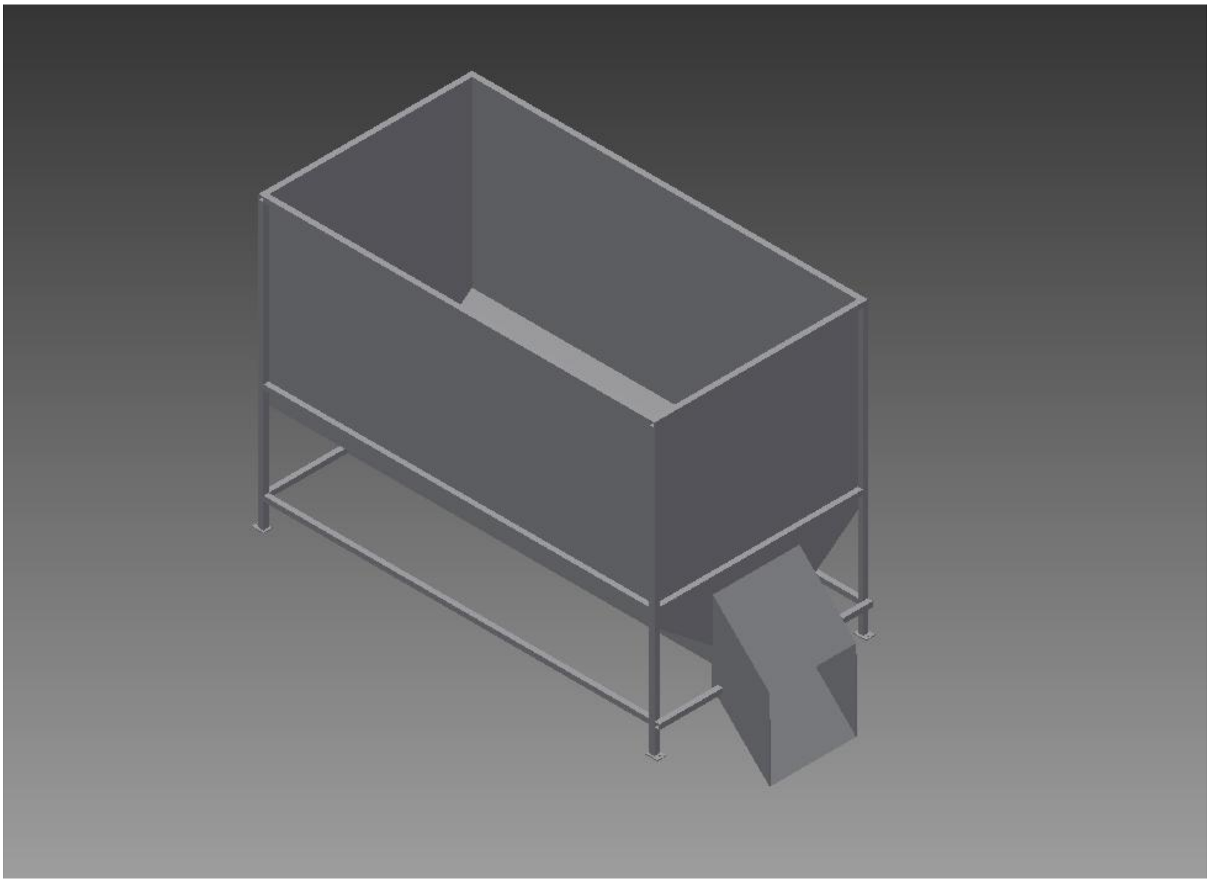


Figure A - Initial Skeletal Layout

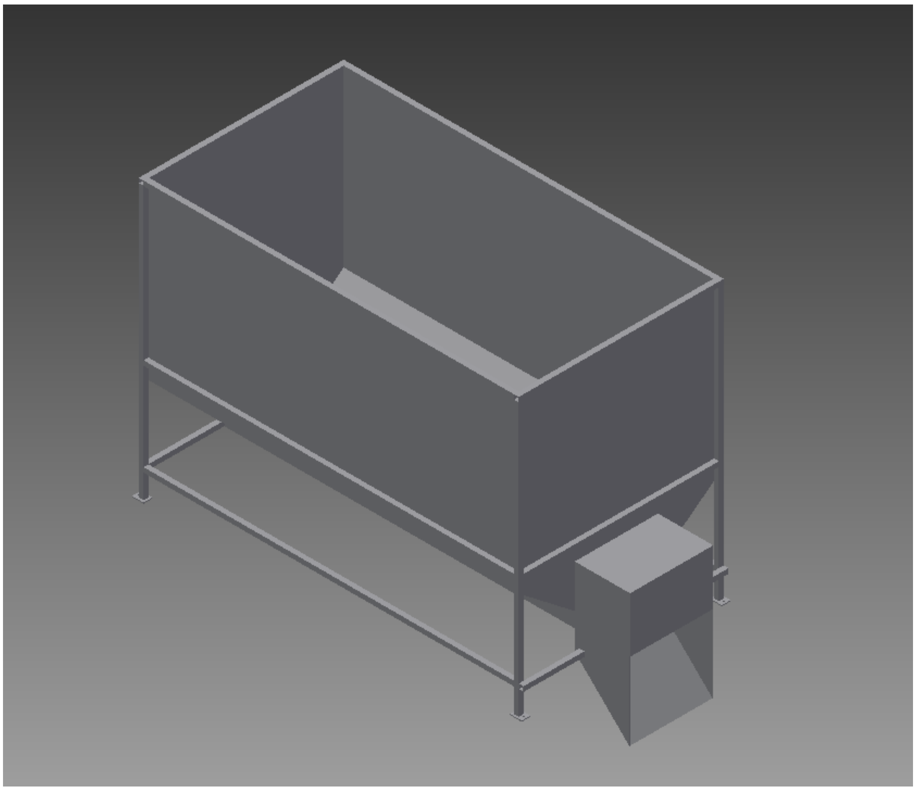
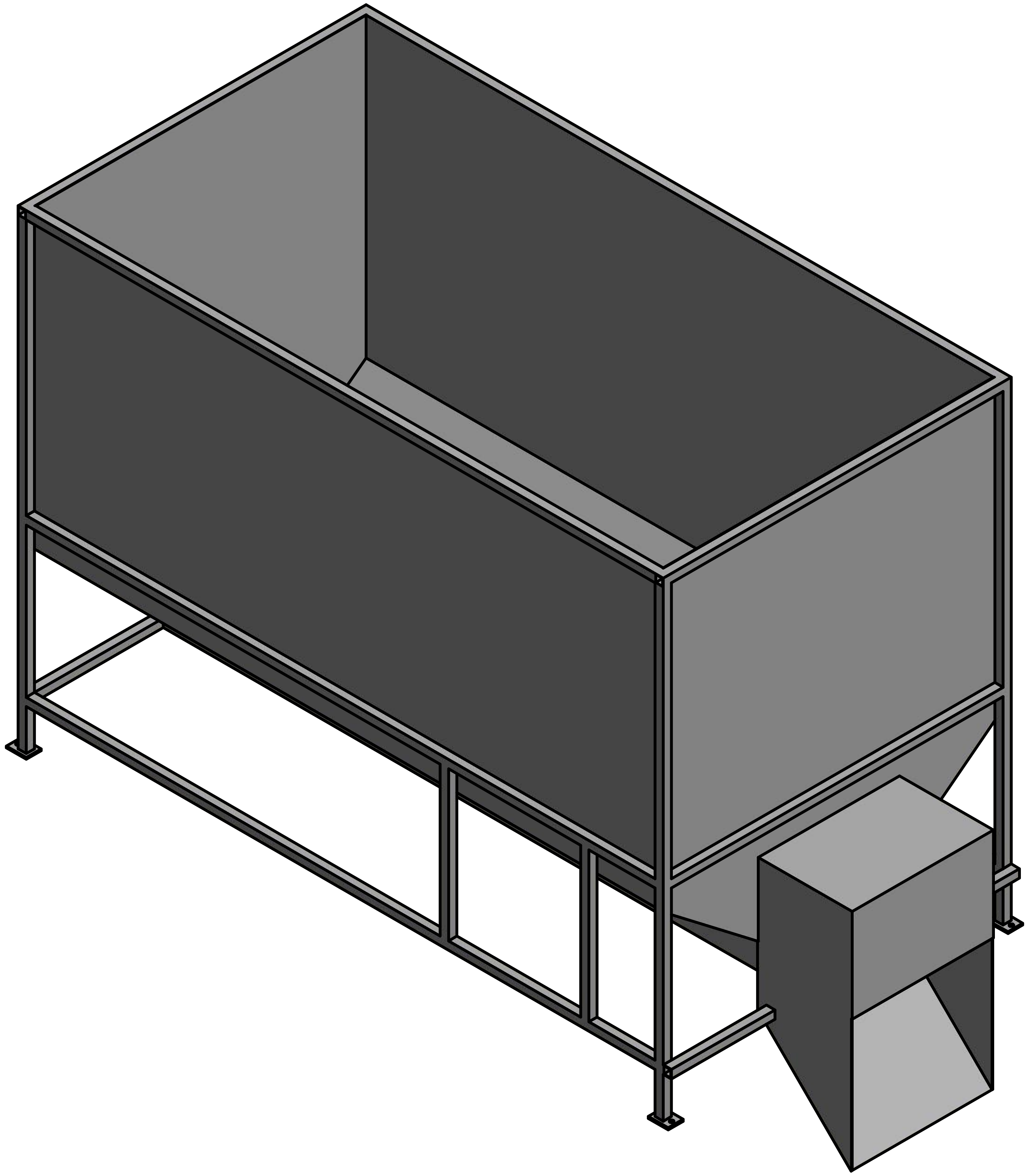


Figure B - Revised Skeletal Layout

Appendix K - Final Prototype Isometric View

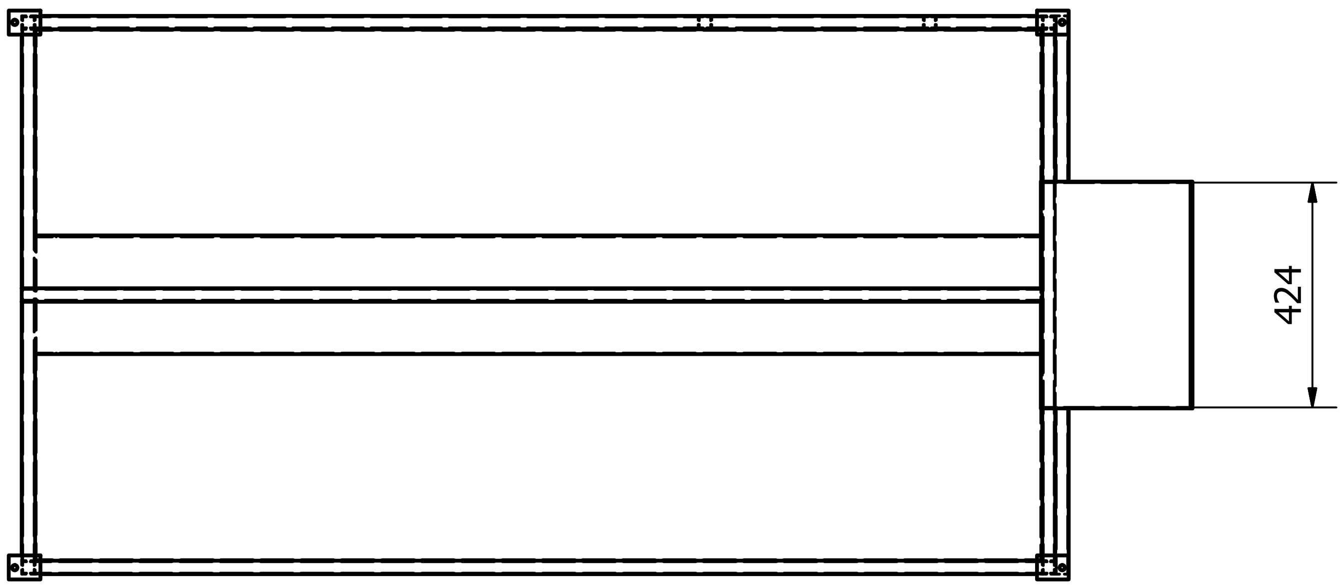


FINAL ISOMETRIC VIEW

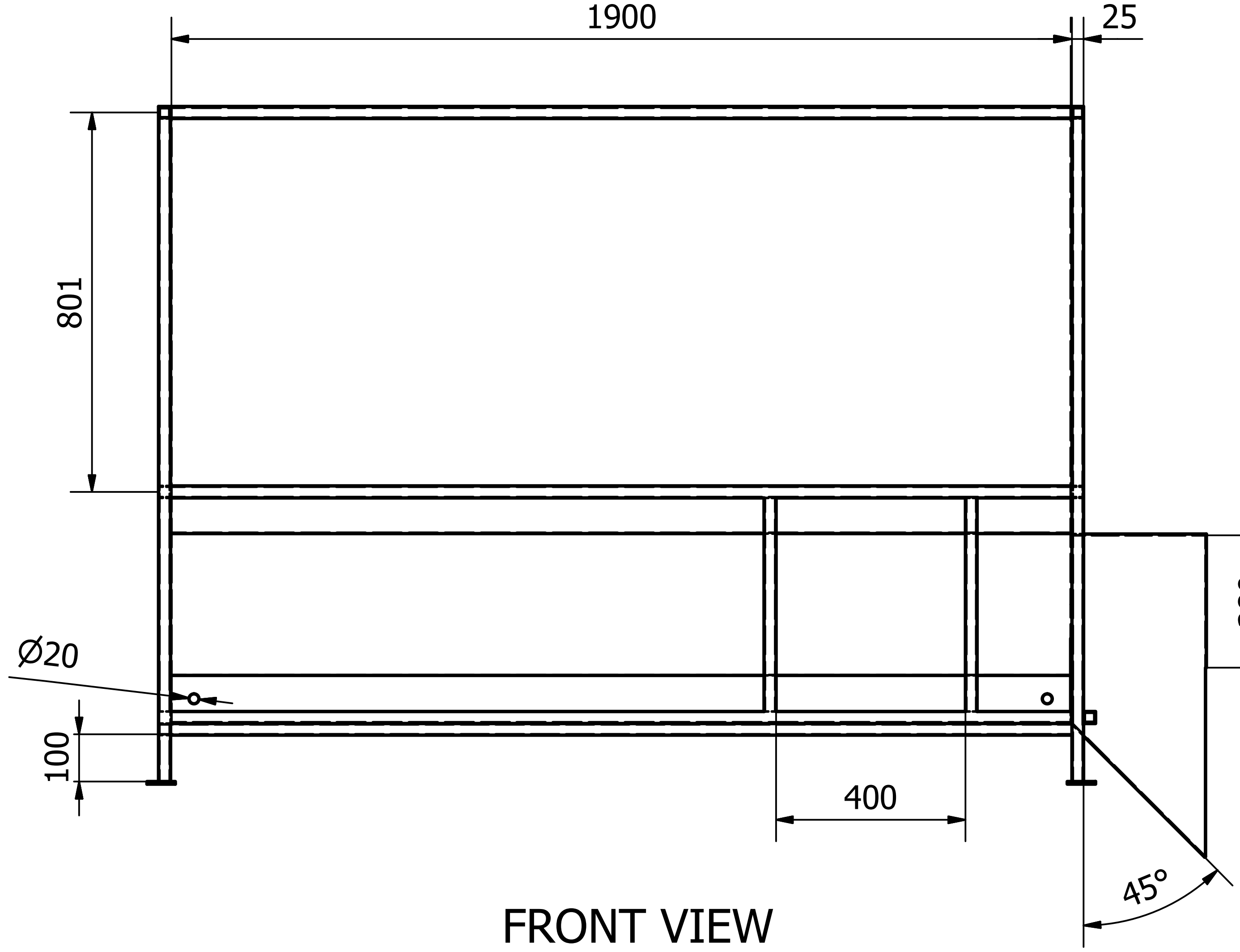
Designed by	Checked by	Approved by	Date	Date
Damien Wooldridge				24/10/2014

White Cottonseed Feeder		
Final Isometric	Edition	Sheet 1 / 1

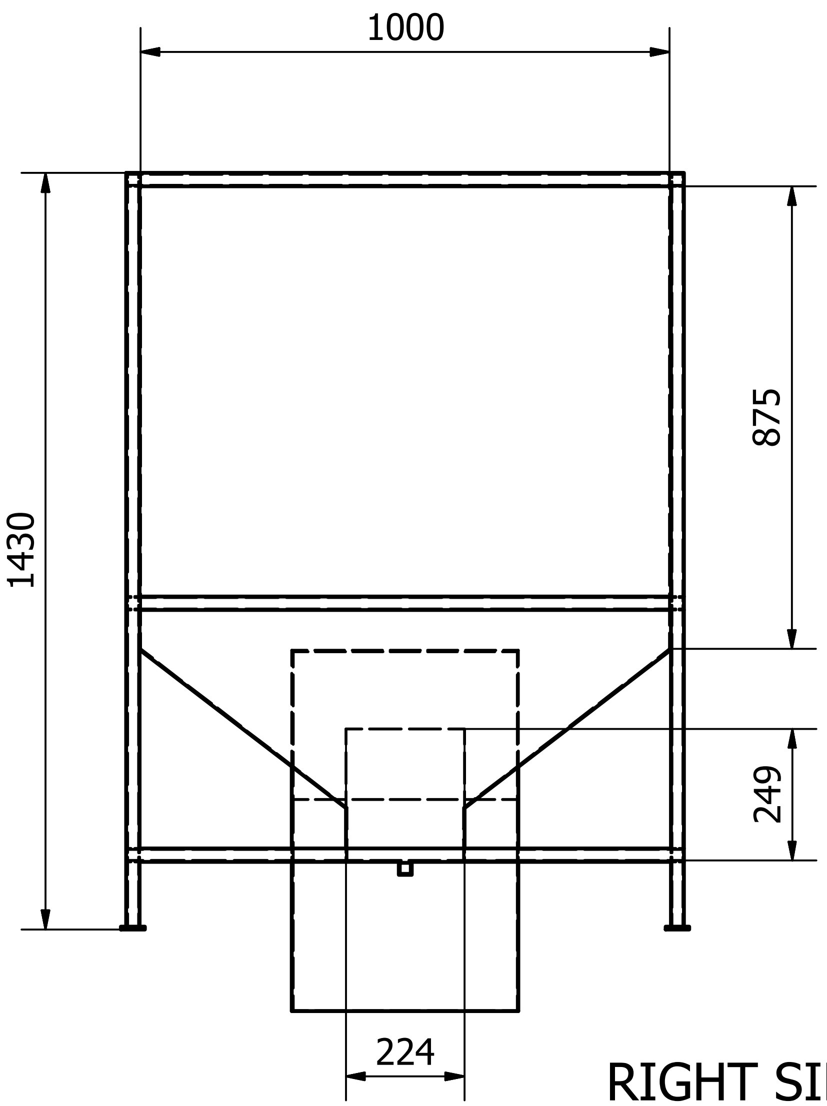
Appendix L - Prototype Detail Drawing



TOP VIEW



FRONT VIEW



RIGHT SIDE VIEW

Designed by	Checked by	Approved by	Date		Date	
Damien Wooldridge					24/10/2014	

White Cottonseed Feeder			
Prototype Detail Drawing	Edition	Sheet 1 / 1	