Palm Tree Processing

Coconut Sweetening Process

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Introduction

Sweetened coconut flakes are a popular confectionery product used in a broad array of foods. Coconut flakes enhance various food properties such as texture, flavor, and visual appeal. Griffin Foods is one of many companies that sweeten and package desiccated coconut flakes for placement into the retail marketplace. A bag of their coconut is pictured in Figure 1.

Figure 1. Griffin's Coconut Flakes

Problem Definition

After learning that many consumers demand the longest length of coconut flakes possible, Griffin Foods examined their coconut product. They noted a decrease in flake length after processing, as seen in Figure 2. When compared to competitors such as Baker's and Mounds, the coconut Griffin's produces is noticeably shorter. To remedy this, Griffin's contacted the Palm Tree Processing Group. In an initial meeting, the team learned that the major distributor of Griffin's coconut flakes prefers the sweet flavor of Griffin's but desires the length of the leading competitors. The Palm Tree Processing Consulting Group worked with Griffin's to improve the length of their coconut flakes.

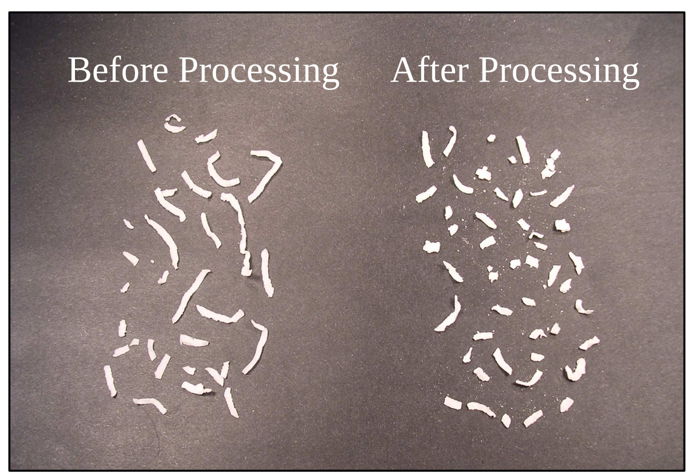


Figure 2. Flake Length Before and After Processing

Project Schedule

The team divided the project into two major parts, corresponding to the fall and spring semesters. Each semester was further broken down into tasks and subtasks. The main tasks for the fall semester included definition of the problem, background investigation, development of a method to determine average flake length, and creation of potential solutions. In the spring semester, the team finished developing the measurement method, researched each potential solution, then tested and analyzed these solutions. Based on research and testing results, the team created a final recommendation for Griffin's.

Statement of Work

Introduction

Griffin Foods, a family owned and operated business, looks to provide consumers with the highest quality food products available. During sweetening of their coconut product, Griffin's notes a decrease in flake length. This length degradation may occur during any of five process steps: delumping, conveyance to cooker, cooking and agitating, overnight tempering and packaging, see Figure 3. Palm Tree Processing examined each of these process steps to determine where and to what extent flake length degradation occurs.

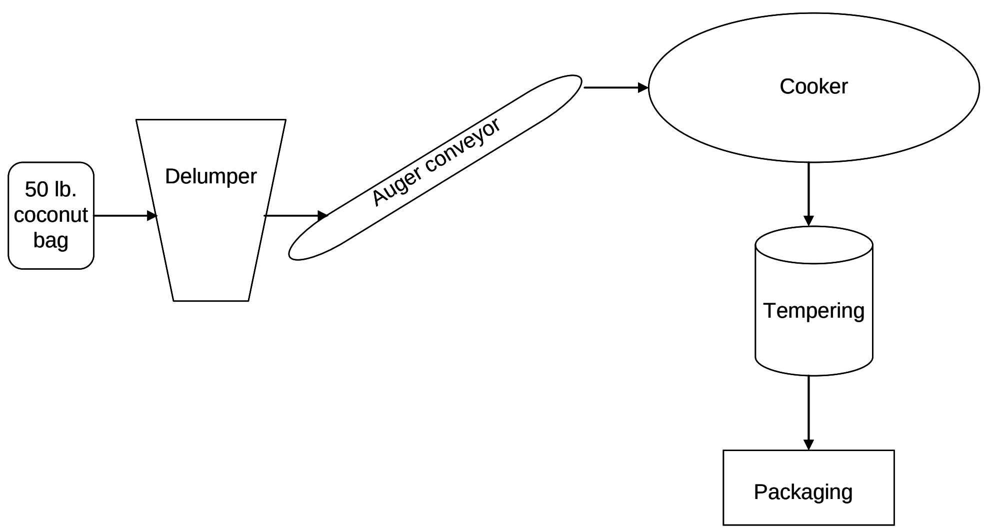


Figure 3. Process Flow Chart

After visiting with various Griffin Foods employees, the team better understood the objectives and limitations of the project. At the completion of the project, the team made recommendations on alternative process equipment and methods. These recommendations should increase final product length, increase processing capacity, and improve the quality of work for employees.

Process Steps

Delumping

Pre-shredded desiccated coconut is supplied to Griffin Foods in fifty pound bags. The coconut in these bags often hardens during storage, forming large clumps. These clumps must be separated before processing to ensure uniform sweetening. Each bag of coconut passes through a delumper comprised of rotating spikes to separate these clumps. Griffin Foods employees designed and built their current delumper, shown in Figure 4.

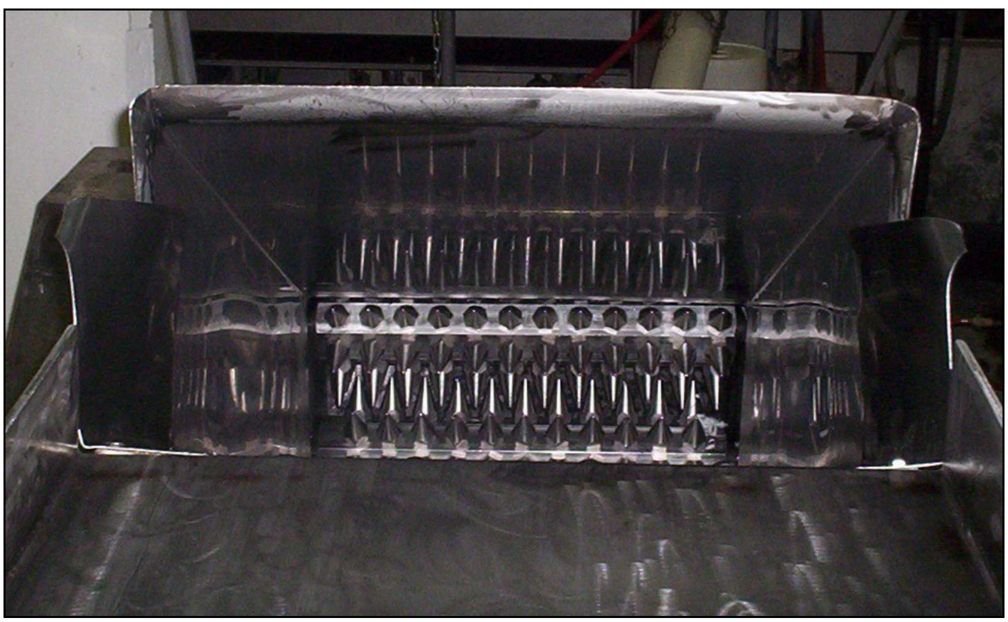


Figure 4. Delumper

Conveyance to Cooker

The next step in processing is conveyance of coconut flakes to the cooker by use of an auger contained within a PVC pipe, as shown in Figure 5. The conveyor operates at 30 hertz to maintain acceptable production capacity. The dimensions of the conveyor are as follows: horizontal length of 124 inches, vertical length of 77 inches, and diagonal length of 140 inches. This conveyor frequently clogs, therefore increasing production time. Often only one employee works the sweetening process line so if the conveyor clogs, he must stop what he is doing and manually shake it to unclog it.

Figure 5. Auger Conveyor

Cooking and Blending

Figure 6. Double Ribbon Agitation Cooker

Griffin Foods currently uses an agitation-type cooker with a volume of 20 cubic foot. Two ribbons, as seen in Figure 6, rotate in opposite directions to ensure blending of the coconut with the slurry. The direct agitation of the ribbons causes product degradation as the flaked coconut grinds against the sides of the cooker. This agitation occurs throughout the entire conveying process and during cooking.

Tempering

After cooking, the batch of coconut is emptied into barrels for overnight tempering as shown in Figure 7. This ensures uniform moisture distribution throughout the product. No apparent product degradation occurs during tempering, however, clumps form due to the sugar and moisture added from cooking. These large clumps must be separated before packaging.

Figure 7. Tempering Barrels

Packaging

Packaging begins by unloading the barrels into another auger conveyor. This step requires extensive manual labor because of the clumps formed during tempering, as seen in Figure 8. Employees use small paddles to empty the barrels and separate the clumps for the conveyor. After the conveyor, the product passes through a second delumper into the packaging machine. Griffin's employees did not recommend that the team make any modifications to this process step.

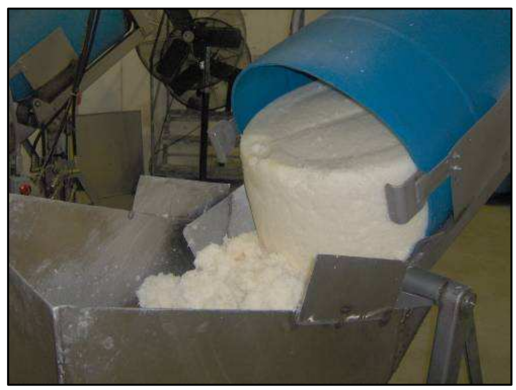


Figure 8. Unloading the Barrel for Packaging

Investigation

Properties of Desiccated Coconut

Griffin Foods uses desiccated coconut from the Philippines to produce their sweetened coconut flakes. According to Woodroof (1970), desiccated coconut is prepared by shredding the coconut meat and drying it to a moisture of 2-5 %. Pneumatic conveyors then send this dried coconut to packaging. After packaging, the bags are stored until shipment. Coconut strands, averaging 1/16 inch in width, often lose palatability and tenderness after prolonged storage and microorganism contamination. Minimizing the storage time before shipment and processing reduces this deterioration.

According to research done by Reginald Child (1964), desiccated coconut should be pure white in color and crisp with a fresh taste. The coconut should contain between 68-72% oil with less than 0.1% free fatty acid. During shipping, the coconut temperature should remain below 35°C or the coconut may exude oil, leading to staining of the product and increased probability of spoilage.

Sweetening and Rehydration Process of Desiccated Coconut

Most American companies use coconut from overseas. This coconut is dried to a moisture content of 5% or less for shipping. Unfortunately, low moisture content flakes have a low quality taste and texture. To improve the quality, moisture is incorporated back into the product. The addition of water alone can actually decrease the final product quality by producing a matted texture and off-flavor. The use of humectants, such as creamed coconut, prevents these problems.

U.S. Patent 4363825, submitted by General Foods Corporation (1981), describes one of the various ways to rehydrate and sweeten coconut flakes intended for bakery and/or confectionery purposes. During shipping and storage, flakes compact together and may form chunks or bricks of coconut. General Foods first step in creating sweetened coconut separated these chunks by steaming the bag for up to 60 seconds. The coconut remained in its original shipping bag during both the steaming and the dead time before the next step. Following steaming, General Foods dumped the coconut flakes from the shipping bag into a churn rotating between 10 to 14 rpm. Once at 65°C, they sprayed a creamed coconut and propylene glycol solution onto the coconut flakes for 2 to 8 minutes. After coating the flakes with liquid, powdered sugar is applied onto the coconut for 4 to 6 minutes. This mixture then churned for up to 5 more minutes. To ensure uniform moisture distribution, they removed the coconut flakes from the churn and placed them into a stainless steel container for up to 170 hours.

Woodroof (1970) describes another method to rehydrate desiccated coconut. The process began by loosening the coconut by injecting steam into the bags. Employees then placed the coconut into a mixer where addition of the slurry occurs. Employees prepared the slurry by dissolving invert sugar in water and heating this mixture to 180°F. They ran the mixer on low speed for 2-3 minutes to blend the desiccated coconut with the slurry. After mixing, the blended coconut and slurry sat for 15-30 minutes. This formula produced a product with 11-12% moisture content.

Classification and Measurement of Desiccated Coconut

Classification Standards

Numerous companies throughout the world produce grated desiccated coconut. Two standards exist for classifying coconut flakes by length: Codex Standard 177 and Thai Industrial Standard 320-2522.

Codex (2001) created a classification system for the commercialization of grated coconut. Codex Standard 177 specifies three types of coconut based on granulometry: extra-fine, fine or medium. Appendix A contains this standard in its entirety.

Standard 320-2522, developed by Thai Industrial (1979), specifies grades, marking, sampling and other criteria for classifying desiccated coconut. They developed 5 grades on the basis of particle size: coarse, medium, fine, super fine, and fancy. This standard is located in Appendix B.

Measurement Methods

The American Society of Agricultural Engineers (1988) developed a standard to measure the average length of chopped forage materials, see Appendix C. The method involved the screening of particles through sieves stacked vertically, with the largest apertures at the top and the smallest at the bottom. The sieves were filled with the material to be tested, and then oscillated at a certain frequency to sift the particles through the screens. After sifting, the weight in each sieve was measured. Using the weight and the corresponding sieve size in a standardized logarithmic equation, Equation 1, average particle size was calculated.

$$X_{gm} = \log^{-1}\left[\frac{\sum\left(M_i \log \overline{X_i}\right)}{\sum M_i}\right] \qquad \textbf{[Equation 1]}$$

where X_{gm} = geometric mean length

$\overline{X_i}$ = geometric mean length of particles on i^{th} screen

M_i = mass on i^{th} screen

The Journal of Food Engineering (2004) described another measurement method for irregularly shaped materials. It used image analysis to quantify the length of shredded cheese.

Design Criteria

Griffin Foods provided the team with specific requirements to consider while researching and developing potential solutions for the improvement of coconut flake length. These requirements were considered when selecting final recommendations.

One such requirement was that their recipe may not change. Current consumers prefer the sweet flavor of Griffin's coconut product over the flavor of the leading competitors. Any alteration of the recipe could change this desired flavor and/or the physical properties of the coconut.

Any change in process steps must meet or exceed Griffin's present production capacity. It currently takes approximately 12 hours to complete a day's worth of processing. If the capacity decreases, the production time could increase. This would cause labor costs to increase while the quantity of product processed would remain the same.

Another requirement was that any recommendation must easily fit into Griffin's current production line. This would allow for an easy transition from the existing line to the improved line and minimize downtime.

Coconut production is a minor part of Griffin Foods operations, therefore minimal funds are available for any potential improvements. Therefore, Palm Tree Processing took cost into consideration when evaluating potential solutions and making final recommendations.

Concept Development

Before developing potential recommendations, the team determined exactly where and to what extent flake length degradation occurred. This required a method of quantifying flaked coconut length after each process step. The percent degradation for each step could then be calculated using Equation 2.

$$P = \left(\frac{X_n - X_{n-1}}{X_n} \right) * 100\% \qquad \textbf{[Equation 2]}$$

where P = Percent degradation

X_n = Average length of n^{th} process step

X_{n-1} = Average length of previous process step

Measurement Methods and Results

Palm Tree Processing found two methods regarding measurement of the length of shredded or flaked material. The team evaluated each method and chose the best for use with the project.

ASAE Standard S424

ASAE Standard S424 (1988) described one such method. The team modified this standard for use with coconut flakes. The testing procedures were as follows:

- Weigh 255 mL of sample and record
- Align 5 sieves in decreasing size, see Figure 9
  - 9.5 mm
  - 6.3 mm
  - 4.75 mm
  - 3.35 mm
  - 2 mm
- Shake sieve manually for approximately 15 seconds
- Remove each sieve carefully and weigh contents
- Calculate geometric mean length using Equation 1
- Calculate percent degradation using Equation 2
- Repeat for each sample

Figure 9. Sieve Setup

Results

The team tested several samples using the modified ASAE standard and obtained average flake lengths. To verify these results, the team measured a sample of flake lengths by hand. The average length calculated by the team was significantly greater than that calculated using the standard. This method also showed an increase in flake length during processing. Because processing can only degrade flake length, this method proved invalid for use with flaked coconut.

Image Analysis with MatLab

After failure of the modified ASAE standard, the team created a modified version of the image analysis method described in <u>The Journal of Food Engineering</u> (2004) to determine the average flake length of a coconut sample. This method used the computer program MatLab to analyze images of flaked coconut. The testing procedures were as follows:

- Setup 3-bandwidth camera as shown in Figure 10
- Spread coconut sample evenly on black construction paper, careful to avoid overlapping
- Record length between camera and paper
- Capture image of coconut sample as a '.tif' file
- Use Mat Lab to analyze image and determine mean flake length in pixels
- Convert pixels to millimeters
- Calculate average flake length in Excel
- Calculate percent degradation using Equation 2
- Repeat for each sample

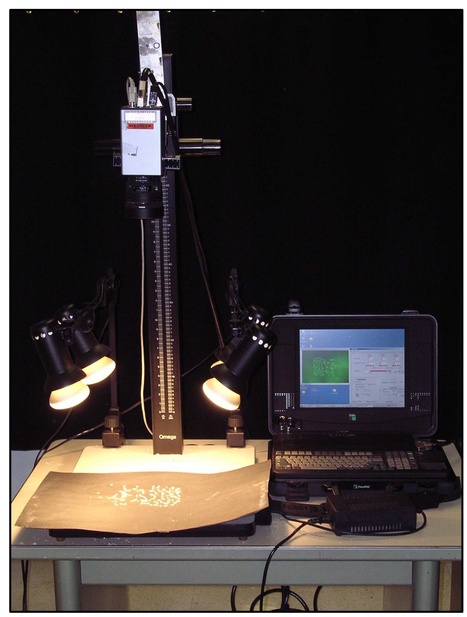


Figure 10. Camera Setup

* **Note:** A detailed instruction manual is provided in Appendix D.

Results

The team tested a set of samples with this method. Images were taken and processed in MatLab. The Image Processing Toolbox in MatLab converted each picture into black and white pixels, see Figure 11, counted the number of white strands, and determined the total area of white pixels. The number of strands and total area were entered into Excel and the average length was calculated, refer to the instruction manual in Appendix D for detailed methods and equations.

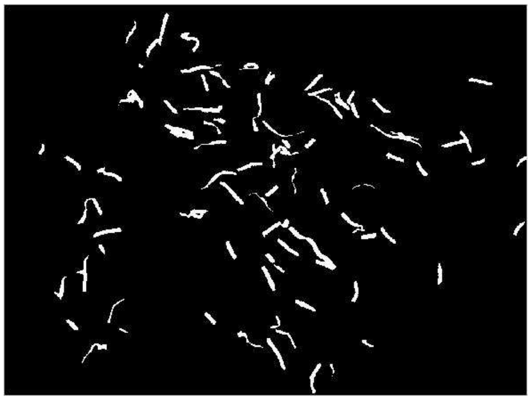


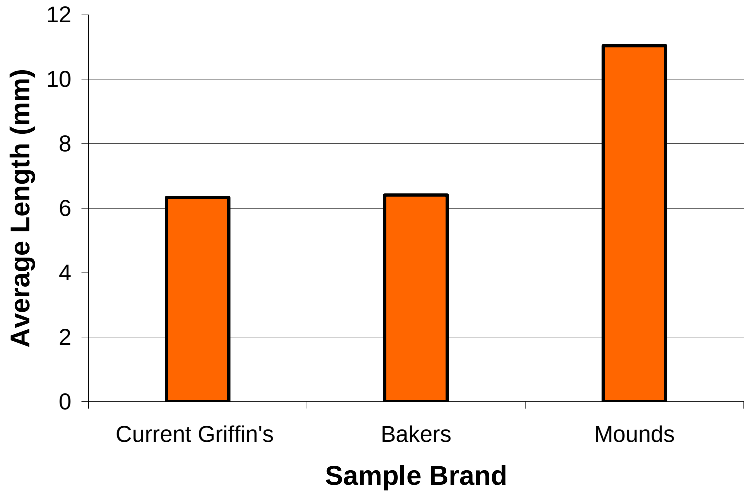
Figure 11. Image Processed in MatLab

As with the ASAE method, the team measured a sample of flake lengths by hand and compared it to the average flake length computed using MatLab. There was only a 10% difference between the two, and the majority of this difference was likely caused by human error when measuring by hand. The team found these results satisfactory and decided to use this method to determine the average flake length for all samples.

Competitor Testing

Palm Tree Processing used the MatLab image analysis technique to compare the average flake lengths of each of the leading competitor's final products to Griffin's final product. The results are shown in Chart 1.

Chart 1. Competitor Length Comparison

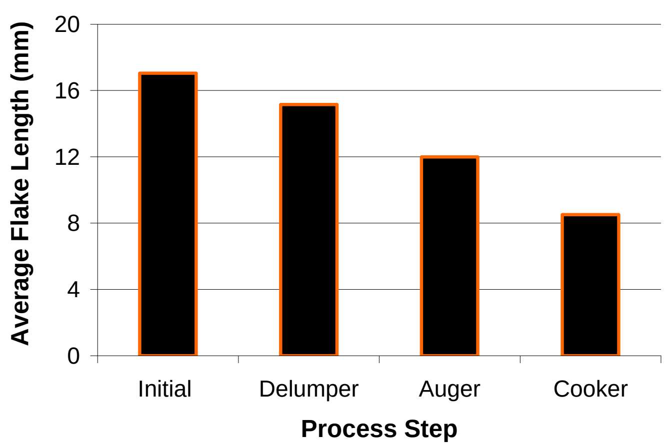


These results show that Griffin's current average flake length is comparable to Bakers. However, a relatively new competitor, Mounds, has an average flake length about 5 millimeters longer than Griffin's. Based on these results, the team aimed to make an improvement in length of 5 millimeters or more.

Sample Testing

Finding the image analysis with MatLab method successful, Palm Tree Processing tested the samples collected after each process step. The team found the average flake length after each step, see Chart 2.

Chart 2. Average Length of Coconut Flakes



Using these lengths with Equation 2, the team calculated the percent degradation for each step. The results are provided in Table 1.

Table 1. Average Length and Percent Degradation of Coconut Flakes

Sample	Average Length (mm)	% Degradation
Initial	17.05	0
Delumper	15.15	11
Auger	11.99	21
Cooker	8.51	29

These results show that the average flake length degrades after each step of the process, with the most degradation occurring in the cooker. The overall degradation from the beginning to the end of the process was 50%. Appendix E contains the raw data for each of the tests.

At the completion of testing and analysis, the team identified where and to what extent flake length degradation occurred. The team based its recommendations on this information.

Testing and Analysis of Potential Solutions

At the completion of the fall semester, the team created three potential solutions: steam injection, replacement of auger conveyor, and replacement of cooker with tumble blender. Before making any final recommendations, the team tested and analyzed or researched each proposal to determine two things: whether the alternative would work for the process and how much, if any, improvement in length it would make.

Proposal A - Steam Injection

Results showed a total of 30% degradation caused by both the delumper and the auger conveyor. The team felt that this would be an ideal part of the process to consider replacing due to the large percent degradation. During the literature review, the team discovered that another coconut processing company used direct steam injection to break up clumps of coconut flakes that formed during storage. Based on this information, one of the potential solutions was to replace Griffin's current delumper and conveyor with a direct steam injection system.

Testing and Results

After researching steam injection, the team did not find a direct steam injection system that resembled the system mentioned in U.S. Patent 4363825. However, they did find steam equipment, such as steam tables or steam blanchers, which could be suitable alternatives.

To determine if Griffin's should implement a steam system, the team looked to test one such system. They met with Dr. Tim Bowser, associate professor in Oklahoma State University's Biosystems and Agricultural Engineering Department, and he recommended that they first test the steam table in the Food and Agricultural Products Center (FAPC) to determine if steam could successfully separate clumps of coconut. The team met and ran several tests with the steam table. The results are summarized in Table 2.

Table 2. Steam Table Results

Total Steaming Time (sec)	Coconut Clumps Broken Up?
10	No
30	No – only the immediate outside was broken up
60	No – a large clump remained in the middle
90	Yes

These results showed the team that a steam system could possibly replace the delumper if steam is applied for at least 90 seconds. However, the steam time could not exceed 90 seconds if the current production capacity was to be maintained. Two 50 pound bags of coconut were used for these tests and when the bags were opened, only a few clumps remained. The team decided to run a second test at a later date with a different coconut sample to verify that the steam system would work for each and every bag of coconut.

At a second visit to Griffin's, the team shared the results of the first test. Griffin's employees said that there could be no change in color of the coconut flakes with a steam system. The team also received a bag of coconut that was similar to a hard brick. They tested this bag with the same conditions that were successful in the first test. The test showed no apparent color change, but the steam unsuccessfully separated the coconut clumps. A large clump remained in the middle of the sample, with several other small clumps surrounding it, see Figure 12.

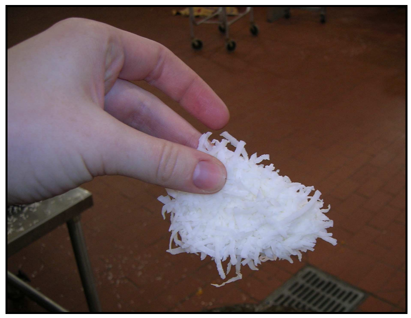


Figure 12. Sample Coconut Clump after Steaming

The results of the second test proved to the team that a steam system would not be a suitable replacement for the current delumper because it would not fulfill each of the project goals, namely to improve Griffin's current process line capacity.

Proposal B - Replacement of Auger Conveyor

After the initial visit to Griffin's, the team believed that a major improvement in coconut length could be made by replacing the auger conveyor with an alternative type of conveyor. The results showed a 21% degradation of coconut flake length after auger conveying, confirming the team's initial observations. At the end of the fall semester, the team proposed replacing the auger conveyor with a pneumatic or bucket conveyor.

Pneumatic conveyors use air to move materials such as chopped forage and grains of short to medium length. They have variable capacities with the potential for high speeds, but also have high power requirements.

Bucket conveyors utilize buckets attached to a chain or belt to move free flowing materials such as grains, flakes, or chips. They have high capacities while efficiently and gently handling materials, but can require extensive maintenance due to the large number of moving parts.

Research Results

At the beginning of the spring semester, the team met with Dr. Brusewitz, professor emeritus in Oklahoma State University's Biosystems and Agricultural Engineering Department, to discuss the various types of conveyors. Teaching such courses as 'Processing Agricultural Materials' and 'Food Engineering,' he was knowledgeable on each of the different conveyor types available and their suitable applications. He did not recommend using a bucket conveyor because of the short conveying length, required incline, and numerous moving parts. He also did not recommend the pneumatic conveyor. Pneumatic conveyors have high power requirements, can be very costly, and are best used for longer distances. He did, however, recommend using an inclined flighted belt conveyor for the desired application. Figure 13 shows one example of an inclined flighted belt conveyor.

Figure 13. Inclined Flighted Belt Conveyor (www.kamflex.com)

To determine whether an inclined flighted belt conveyor would be a suitable alternative for the auger conveyor, the team looked to test one. They contacted several different companies that supplied this type of conveyor, such as Food Processing Equipment Co. (FPEC) and Meyer Industries, and none of them had a conveyor available for testing. The team went back to Dr. Brusewitz who suggested contacting the local grain and cement mills. The OSU feed mill had several different conveyors, but nothing similar to a flighted conveyor. A representative of Dolese Concrete told the team that he did not know of a flighted belt conveyor anywhere around Stillwater. Finding the grain and concrete mills unsuccessful, the team talked to Dr. Weckler, assistant professor in Oklahoma State University's Biosystems and Agricultural Engineering Department. He recommended contacting other universities. The team called the University of Arkansas, Kansas State University, and Texas A&M University. None of these universities knew of any flighted belt conveyors the team could test.

At this point the team turned to research and publications to validate recommending an inclined flighted belt conveyor. Two separate articles were found that supported using belt conveyors over other conveyor types. Dave Norheim, sales manager for Brandt Ag Products, stated that numerous grain handlers have switched from auger to belt conveyors due to an increased concern with seed quality (Johnson, 2005). He said that belt conveyors not only help maintain product quality, but also require half as much power and can increase capacity when compared to auger conveyors. The Prairie Agricultural Machinery Institute (PAMI) noted similar observations. They conducted a study to determine the effect of conveyor type on grain quality. Their findings showed that belt conveyors impart the least amount of damage on grain (about 1%), whereas auger conveyors did the most damage on the grain (about 3%) (PAMI, 2002).

Proposal C - Replacement of Cooker with Tumble Blender

Results showed an average of 29% degradation of coconut flake length after cooking and blending. Based on observations of Griffin's employees during a trip to another coconut processing facility, the team looked into replacing the ribbon agitation cooker with a tumble blender. A tumble blender is essentially a chamber with a single agitation bar going through its center. This bar can add liquid ingredients as the chamber rotates, allowing gravitational forces to mix the components. This form of mixing produces a minimal amount of shear to the product. There are currently several tumble blender vessel shapes available including: slant-cone, double-cone, and V-shaped.

A slant-cone tumble blender consists of a cone-shaped chamber mounted at an angle to the ground, as shown in Figure 14 (Gemco, 2004). This angle causes uniform blending with the back and forth motion of the product during rotation. This design also offers a very fast blend time with minimal blend variation. However, it requires a large headspace.

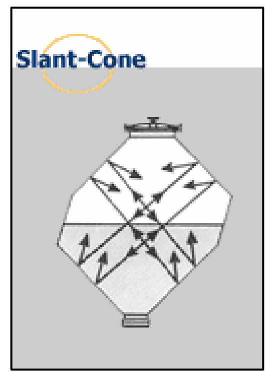


Figure 14. Slant-Cone Tumble Blender

The double-cone blender is made of two cones that rotate around the support bar, as shown in Figure 15 (Gemco, 2004). The compact design of the double-cone blender allows for greater blending volumes with minimal space requirements when compared to other blender shapes. Due to decreased movement within the chamber, this shape requires a longer blending time.

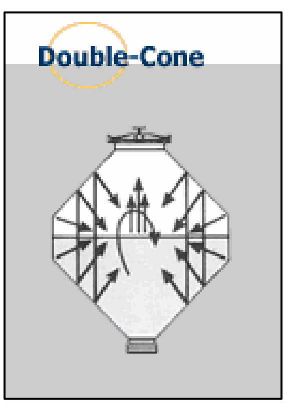


Figure 15. Double-Cone Tumble Blender

The V-blender consists of a V-shaped chamber seen in Figure 16 (Gemco, 2004). This shape causes the product to separate and intermesh continuously during rotation. The V-shaped tumble blender design offers very efficient blending, but can be difficult to clean.

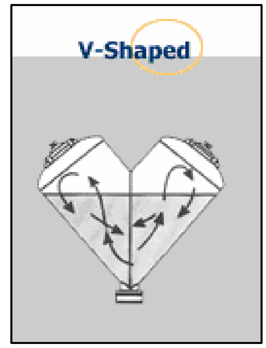


Figure 16. V-Shaped Tumble Blender

Testing and Results

This semester the team explored the differences between Griffin's current ribbon-agitation cooker and a tumble blender. The most obvious difference the team noted was that a tumble blender does not add heat while mixing the ingredients, whereas Griffin's current process adds heat throughout. Palm Tree Processing tested the effects that V-shaped tumble blenders had on coconut flake length during processing using two different blenders and different methods of adding ingredients.

The FAPC at Oklahoma State University houses a lab-sized V-shaped tumble blender manufactured by Patterson-Kelley Company, see Figure 17. The team used ingredients from Griffin's processing plant in Muskogee, OK while testing this tumble blender. These ingredients consisted of premixed sugar slurry and unprocessed coconut. However, the ingredients remained in storage for four weeks before testing was performed. This allowed the solid ingredients in the slurry to precipitate. To correct this, the slurry was heated and mixed in a steam-jacketed kettle to 195°F. After the ingredients were prepared, the V-shaped tumble blender was filled to approximately one third of its total size with Red V desiccated coconut flakes. The heated slurry was then added directly into the blender with the coconut

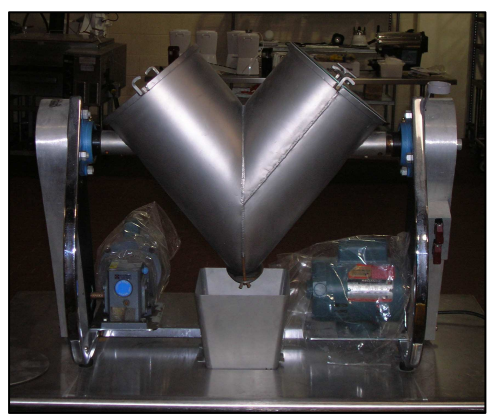


Figure 17. FAPC V-Blender

flakes. The team ran the blender for 10 minutes. After this processing, the team noticed that the texture of this product did not appear similar processed at Griffin's. Results of image analysis with MatLab showed a degradation of only 10% as compared to 29% using Griffin's cooker.

After this initial testing, the team attempted a second test using the V-shaped blender at the FAPC. For this test, the team mixed the raw ingredients of Griffin's slurry minutes before processing. This slurry was heated to 200°F the added to the coconut in the blender. For this test, the team filled the blender to two thirds of its capacity. After an initial blending period of 8 minutes, powdered sugar was incorporated into the blender in accordance with Griffin's current recipe. The blender then ran for an additional 7 minutes. The product appeared similar to the results of the previous test, but formed large balls of coconut, see Figure 18. Using Matlab, the team determined the degradation of this test to be 34%

Figure 18. Coconut Balls Formed after Blending

After analyzing the results from the preliminary tests, Palm Tree Processing contacted the Patterson Kelley Company and arranged further testing at their pilot facility in East Stroudsburg, PA. Dr. Tom Chirkot, an expert on tumble blenders, prepared an eight liter-capacity, V-shaped tumble blender with a low-shear high-speed intensity bar for coconut processing, see Figure 19. The low-shear high-speed intensity bar passes through the center of the blender and allows for uniform distribution of liquid ingredients with minimal shear to the product during mixing. Dr.

Chirkot informed the team that the intensity bar maximizes the blending performance of the V-shaped blender. For both of the tests performed, eight liters of dry ingredients were added to the blending vessel.

Figure 19. Patterson Kelley V-Blender

The first test at Patterson Kelley's facilities consisted of blending all of the dry ingredients in the blender for one minute, followed by addition of the liquid components of the slurry. The unheated slurry was added through the high-intensity bar at room temperature over the course of three minutes. After the addition of the slurry, the ingredients mixed for an additional minute. The product exhibited no signs of clumping after processing, but did not appear identical to the product processed by Griffin's current cooker. Results of MatLab image analysis showed a degradation of 9% during the test.

In the second test at Patterson Kelley's facilities, the team prepared the slurry in a method identical to Griffin's current practice, except for the absence of salt. The dry coconut flakes and salt were added to the blending vessel and allowed to tumble for 30 seconds. The slurry was then pumped through the high intensity addition bar at 160°F over the course of six minutes. Dr. Chirkot then opened the vessel and added the additional powdered sugar called for in Griffin's recipe. The vessel was closed and allowed to tumble for three minutes. After completion of blending, the product appeared identical, both visually and texturally, to that currently processed at Griffin's facilities. Results of MatLab image analysis showed a degradation of 6% during this test. A summary of the results of all tumble blender tests are summarized in Table 3.

Table 3. Blender Degradation Results

Type of Blender	Percent Degradation
Griffin's Ribbon Cooker	29%
FAPC V Blender – Test 1	10%
FAPC V Blender – Test 2	34%
Patterson Kelley V Blender – Test 1	9%
Patterson Kelley V Blender – Test 2	6%

The results of the FAPC tests as compared to the Patterson Kelley tests show that the low-shear high-speed intensity bar is essential in minimizing degradation while preserving a product similar to that currently produced by Griffin's. Blending the ingredients without the high intensity addition bar resulted in a product unlike that of Griffin's and, as seen in the FAPC Test 2, actually degraded the coconut more than Griffin's current cooker. The results between the two Patterson Kelley tests show the importance of heating the slurry. Failure to add heat to the slurry caused an extra three percent degradation and also resulted in a product unlike that of Griffin's. Overall, the results show that degradation can be reduced by more than 20% while maintaining a product similar to Griffin's when using a V-shaped tumble blender equipped with a low-shear high-speed intensity bar.

Cost Analysis

When evaluating the potential solutions, the team analyzed the cost of each. Table 4 shows the projected cost of each recommendation, see Appendix F for detailed cost sheets.

Table 4. Cost Summary

Equipment	New Cost	Used Cost
Image Analysis Package	$2,879	---
Cleated Belt Conveyor	$10,520	$5,000
V-Blender with intensifier bar	$120,000	$25,000

Kamflex quoted the new cost of a cleated belt conveyor and Patterson-Kelley quoted the new cost of a V-blender with intensifier bar. The team researched similar used equipment and found an average cost.

Final Recommendation

Palm Tree Processing's final recommendation to Griffin Foods consists of three parts. First, the team recommends that Griffin's purchase the MatLab image analysis package to monitor length quality in future applications. This package would allow Griffin's to pinpoint any source of degradation when altering their recipe for new customers or when modifying their process for any reason. It would also put Griffin's ahead of their major competitors because none of them currently have a system to quickly and accurately quantify flake length.

The second recommendation is for Griffin's to replace their auger conveyor with a cleated belt conveyor, specifically Kamflex series 811. Research showed that this replacement could reduce degradation by two thirds. It would also increase productivity because this type of conveyor rarely clogs, unlike the current auger conveyor which clogs frequently.

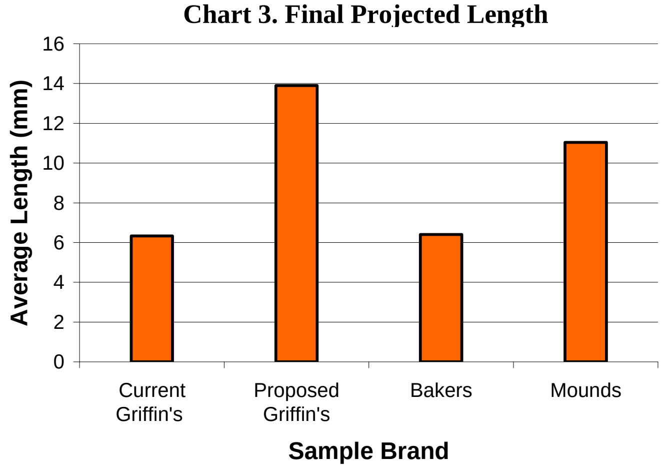
The last portion of the team's recommendation is to replace the ribbon agitation cooker with a Patterson Kelley 20 cubic foot V-shaped tumble blender with a low-shear high-intensity liquid addition bar. This replacement would reduce the current degradation of the cooking step by 23%. It would also increase Griffin's current productivity because it requires less time for uniform blending.

Palm Tree Processing believes that these recommendations fit each of the design criteria set forth by Griffin Foods early on in the project. They will prevent flake length degradation, maintain Griffin's current recipe, and increase productivity all at a reasonable cost. These recommendations would also allow for an easy transition into Griffin's current line because of the similar dimensions of the old equipment to the new.

For both of the equipment replacements recommended, the team suggests that Griffin's purchase new equipment because they would both come with personnel training, technical support, and a guarantee. The used equipment researched by the team was not identical to that quoted by Kamflex and Patterson Kelley, and would not come with the features included with the new equipment.

If Griffin Foods implemented each of these recommendations, the team projects a length improvement of approximately 7 millimeters as seen in Chart 3. This shows that the new average flake length would be more than double the current length. A length improve of 7 millimeters surpasses the team's goal of 5 millimeters and would place Griffin's as the producer of the longest average coconut flakes on the market.

Chart 3. Final Projected Length



References

ASAE Standards. 1988. S424: Method of Determining and Expressing Particle Size of Chopped Forage Materials by Screening. St. Joseph, Mich.: ASAE.

CODEX. 2001. CODEX Standard 177: Grated Desiccated Coconut. CODEX. Available at: www.codexalimentarius.net/web/standard_list.jsp. Accessed 25 October 2005.

Coker, G. C. 1981. Process for making a coconut product. U.S. Patent No. 4363825.

Child, R. 1964. *Coconuts*. 2nd ed. London: Longman Group Limited.

Johnson, A. 2005. Belt conveyors draw farmer interest at Big Iron. Farm and Ranch Guide. Available at: www.farmandranchguide.com/articles/2005/10/13/ag_news/production_news/prod23.txt. Accessed 04 April 2006.

GEMCO. 2004. Principles of Tumble Blending. General Machine Company. Available at: www.okgemco.com/princ_tumblend/prince_blend.html. Accessed 05 November 2005.

Guanesekaran, S., and H. Ni. 2004. Image processing algorithm for cheese shred evaluation. *Journal of Food Engineering* 61(1): 37-45.

PAMI. 2002. Conveying Equipment for Pulse Crops. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/eng3136. Accessed 06 April 2006.

TIS. 1979. TIS 320-2522: Standard for Desiccated Coconut. Thai Industrial Standards. Available at: www.foodmarketexchange.com/datacenter/product/fruit/coconut/detail/dc_pi_ft_coconut1102_0501.htm. Accessed 24 October 2005.

Woodroof, J. G. 1970. *Coconuts: Production, Processing, Products*. Westport, CT.: The AVI Publishing Company, Inc.

Appendix A: Codex Standard 177

Please see attached.

Appendix B: TIS 320-2522

Thai Industrial Standards TIS 320-2522 (1979) Standard for Desiccated Coconut

Date of Establishment: 2 November 1979
Date of Public Notice in the Government Gazette: 20 February 1980

In the event of any doubt or misunderstanding arising from this translation, the standard in Thai will be held to be authoritative.

1. Scope

1.1 This standard specifies grades, requirements, food additives, hygiene, container, weight and measure, marking and labeling, sampling and criteria for conformity for desiccated coconut.

2. Definition

For the purpose of this standard, the following definition applies:

2.1 DESICCATED COCONUT: The product obtained by drying the granulated or shredded white meat of the fully mature coconut kernel, Cocos nucifera Linn. by means of a mechanical air drying.

3. Grades

Desiccated coconut shall be of 5 grades when classified on the basis of article sizes by means of mechanical sifting.

3.1 Coarse shall be as follows.
3.1.1 Particle size: 3.35 mm to 4.76 mm, not more than 15% by weight
3.1.2 Particle size: 2.00 mm to 3.35 mm, not less than 70$ by weigh
3.1.3 Particle size: less than 1.AU mm, not more than 2.5$ by weight
3.2 Medium shall be as follows.
3.2.1 Particle size: 2.00 mm. to 2.80 mm, not more than 15% by weight
3.2.2 Particle size: 1.40 mm to 2.00 mm, not less than 70% by weight
3.2.3 Particle size: less than 1.00 mm, not more than 2.5% by weight
3.3 Fine shall be of 1.40 mm to 1.68 mm, not more than 15% by weight.
3.4 Super fine shall be of less than 1.00 mm.
3.5 Fancy type shall be of the bigger size and of the shape different from those specified in clauses 3.1 to 3.4.

Remark: The sieve aperture size in mm is equivalent to B.S. mesh No. as given in the table below.

The sieve aperture sizemm	B.S. meshNo.
1.00	16
1.40	12
1.68	10
2.00	8
2.80	6
3.35	5
4.76	-

4. Requirements

4.1 General requirements
Desiccated coconut shall be natural white, crisp and sweet having natural taste of coconut. It shall be free from rancidity, musty or other objectionable odour, insect infestation, fungus and foreign matter.

4.2 Parings The brown specks due to parings in coarse or medium grades shall not exceed 10 particles per 100 g when tested by the method prescribed in clause 10.2.

4.3 Colour The colour of desiccated coconut shall not be deeper than 0.2 Red, 0.7 Ye11ow and 0.1 Blue on the Lovibond tintometer scale for all grades when determined by the method prescribed in clause 10.3.

4.4 Bacterial contamination 4.4.1 Desiccated coconut shall not contain bacteria of the Salmonella group in each 50 g of sample when tested by the method described in clause 10.4. 4.4.2 The coliform count shall not exceed 10/g when tested by the method described in clause 10.4.
4.5 Chemical requirements The product shall comely with the chemical requirements given in Table 1.

Table 1 Chemical requirements (clause 4.5)

Item	Requirement	Analysis as clause
Moisture content, max. % by weight	3	10.5
Oil content, min. % by weight	60	10.6
Free fatty acid, aslauric acid, max. % by weight of extracted oil	0.3	10.7

5. Hygiene

5.1 The hygiene of product shall conform to TIS 34-1973, Standard for General Principles of Food Hygiene.

6. Container

The container shall be clean, strong, durable, hermetically sealed and free from undesirable odour.

7. Weight and measure

7.1 Net weight of each container shall not be less than that declared on the label.

8. Marking and labeling

8.1 The label shall conform to TIS 31-1973, Standard for General Principles of Labelling Industrial Products.
8.2 At least there shall be figures, letters or code indicating the following information clearly and legibly on each container.
(1) Name of the product "Desiccated coconut"
(2) Grade
(3) Net weight in SI unit
(4) Code or manufacturing date
(5) Name of manufacturer or factor or trade mark or name of packet or distributor
(6) Country of origin
8.3 Any person who manufactures the industrial products complying with this standard may use the standards Mark in connection with his products only after having received a license from the Industrial Product Standards Council.

9. Sampling and criteria for conformity

Unless otherwise agreed upon, the method of sampling shall be as follows.
9.1 Lot: The product of the same grade and manufactured at the same time.
9.2 Sampling
9.2.1 The product shall be drawn at random from the same lot and the number of containers to be selected shall comply with those specified in Table 2.
9.2.2 The order of containers to be drawn shall be in accordance with the following formula.

$$r = N/n$$

Where r = the order of sample to be drawn
N = lot size
n = sample size

Table 2 Sampling plan (clause 9.2.1)	
Lot size (N)Container	**Sample size (n)Container**
Less than 50	2
51 to 150	3
151 to 300	5
301 to 500	7
501 to 1000	8
1001 and above	9

9.3 Preparation of test samples.

With a pasteurized spoon, approximately equal quantity of the material shall be taken from each of the selected container till the quantity collected is at least 500 g; mixed together in pasteurized, air-tight container and pt at 5-10°C. When tested, the sample shall be divided into two parts, one for micro-organism analysis mid the other for chemical analysis.

9.4 Criteria for conformity

The lot shall be considered as conforming to this standard provided that the: test results on sample obtained from clause 9.3 meet all the requirements specified in clause

Appendix C: ASAE Standard S424

Please see attached.

Calculating the Average Length of Coconut Flakes Using Image Analysis in MatLab

Instruction Manual

Developed by:

Elizabeth Casey
Justin Dillingham
Mohd Hussain
Brady Stewart

With the help of Roshani Jayasekara

Palm Tree Processing

BIOSYSTEMS & AGRICULTURAL ENGINEERING
Oklahoma State University

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INTRODUCTION

At the start of our Senior Design Project, no measurement method existed for the calculation of the average length of irregularly shaped materials. Our team, Palm Tree Processing, researched several different methods and determined that none were suitable for coconut flakes. With the help of one of our graduate students, Roshani Jayasekara, we developed a measurement method using image analysis.

Image analysis with MatLab can be used to determine the average length of materials such as coconut flakes. The image processing toolbox in MatLab converts digital pictures into black and white. It then calculates the white area and the number of white objects. These values are placed into an Excel spreadsheet and the average length is calculated.

When compared to the average length measured by hand, the length calculated with MatLab was extremely accurate. Therefore, we recommend using image analysis with MatLab for the measurement of any irregularly shaped materials, especially coconut flakes.

REQUIRED EQUIPMENT

In order to successfully use this measurement method, we recommend the following equipment:

- Digital Camera*
  - Available at www.ebay.com
  - Item #: HP Photo Smart M307 Digital Camera, 3.2 MP

- Camera Stand*
  - Available at www.bugeyedigital.com/product_index/index001-camera_acc-copy_stands_light_boxes.html
  - Item #: BRA-DIG-DPCS1812

- MatLab Software with Image Processing Toolbox
  - Available at www.mathworks.com

MATLAB®
The Language of Technical Computing

* You may substitute alternative pieces of equipment for those recommended. However, we feel that these would work best for this application.

OPERATING INSTRUCTIONS

The image analysis method involves two major steps: taking the picture and calculating the average length. To achieve accurate results follow the step by step instructions below.

Taking the Picture

- Turn on camera
- Turn off automatic flash
- If available, set picture format to .tif
- Set camera at desired height on camera stand
  - **Note:** keep camera at this height for all pictures
- Spread sample of material, such coconut flakes, on black paper
- Separate any overlapping material, i.e. flakes
- Take picture

Calculating Average Length

- Open MatLab
- Paste in program (see page 4)
- Replace **D:\.tif** with file pathway of picture in line 1 of the program
- Run program by hitting enter
- Read **Area** and **num** off of program output
- Insert into Excel program (see page 6)

MatLab Program

The most important part of this measurement method is the MatLab program. This program converts the desired picture into black and white, counts the number of white objects and determines the total area of white pixels. The program is provided below.

```
I=imread('D:\.tif');
figure,imshow(I)

IR=I(:,:,1);
RED=I(:,:,2);
GREEN=I(:,:,3);

figure
subplot(1,3,1),imhist(IR)
title('IR histogram')
subplot(1,3,2),imhist(RED)
title('RED histogram')
subplot(1,3,3),imhist(GREEN)
title('GREEN histogram')
I2=RED>(120);
figure,imshow(I2,[])


se = [0 1 0;1 1 1;0 1 0];
e=imerode(I2,se);

[L,num]=bwlabeln(e,8);
num

Area=bwarea(e)
imshow(I2), title('Original')
figure, imshow(e), title('Eroded')
```

DEVELOPING A CONVERSION FACTOR

- Look through the camera and mark the actual physical boundary of the photo that will be taken.
- Measure the area of the marked boundary.
- Measure Mat Lab picture screen area, i.e. area on the computer screen.
- Enter both areas in their respective places into the excel chart (i.e. first cell labeled "Average Length (mm)").
- There is no need to correct any other parts of the excel program.
- Below is the actual formula for length conversion. Note that when entering the measured physical area as well as the Mat Lab screen area, it will automatically be entered into the equation below:

Enter both areas in this part of the formula

(((area from Mat Lab*18644)/1444210)*(*area of the marked physical boundary of the photo/Mat Lab picture screen area*)*(1/1.5875)*(1/#of strands from Mat Lab))

where: 1444210 is the # of overall pixels in Mat Lab picture.
18644 is the # of pixels per unit of area of Mat Lab picture.
1/1.5875 is the average strand width

USING THE EXCEL SHEET

- Open the Microsoft Excel program. The Excel spread sheet is already provided with formulas to calculate the average length of coconut flakes, as shown in Table below.

Table 5.1

Process	Sample number	Total area (pixels)	#of strands	Average length (mm)	Average Length of Sample (mm)	Percent Degradation
V-Blender March 8	1	66414	185	12.66	10.81	9.85
	2	60142	165	12.85		
	3	67781	167	14.31		
	4	66788	180	13.08		
	5	49721	139	12.61		
	13	43180	159	9.58		
	14	54010	184	10.35		
	15	56544	185	10.78		
	28	57720	190	10.71		
	29	44872	171	9.25		

- Insert the number of strands obtained from the MAT Lab program into its corresponding column in Excel sheet, as shown in the table.

- Insert the calculated area, obtained from the Mat Lab program in to its corresponding column in Excel sheet, as shown in the table.

- The average length in millimeters will be automatically calculated. The "actual picture area" in the given formula for the average length is developed according to the lab test performed by the coconut processing group. Make sure that you change only the "actual picture area" in the formula depending upon your setup, as shown in the figure below.

Formula for calculating Average Length

(((column 3*18644)/1444210)*(*area of the marked physical boundary of the photo/Mat Lab picture screen area*)*(1/1.5875)*(1/#of strands))

Table 6.2

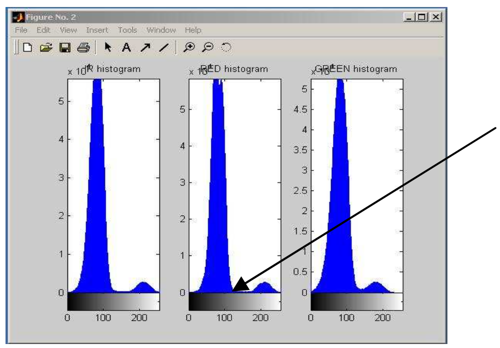
Process	Sample number	Total area (pixels)	#of strands	Average length (mm)	Average Length of Sample (mm)	Percent Degradation
	1	66414	185	12.66		
	2	60142	165	12.85		
	3	67781	167	14.31		

The "average length of the whole sample" in millimeters as well as "percent degradation" will be calculated automatically. The formula for both of these is already included in the Excel program provided.

TROUBLESHOOTING TIPS

If you experience any problems while using this method please refer to the trouble shooting guide below.

Problem	**Possible Cause**	**What to Do**
Picture will not read into MatLab	**Wrong file type**	• Find out if the camera used had the ability to take image/pictures in "*.tiff" format. • If the camera saves the image as "*.jpeg" format, change the format as "*.tiff", using Microsoft Paint or Adobe Photoshop. • Make sure not to make any changes to the image when changing the image format. • Simply open the image using the above mentioned softwares. • Click on "File" and then click on "Save As…" in the drop down menu. When the Save box appears click on "Save as type:" and select "*.tiff" from the drop down menu, and then click "Save" in the Save box. This should save the image in the format specified.
	Wrong file location	• Make sure to specify the correct path name for the image in MatLab as to wherever the image is saved on the computer. For example, "C:\images\picture1.tif". • Also make sure the image is in "*.tiff" or "*.tif" format for MatLab to read.

Dark and bright pictures	**Lighting**	• Make sure the image is taken under good or constant lighting conditions so as to distinguish between black and white areas in the image.
Eroded picture too white or too black in MatLab	**The Red histogram number “I2=RED>(120);”**	• For pictures that are fuzzy or appear too white, change the Red histogram number according to the histogram curve. • Make sure that this number is less than the front end of the peak as shown in the figure below. For example, in the MatLab program, line 15, the number in the “I2=RED>(120);” needs to be approximately 100-110 in the Red histogram curve as shown in the figure below.  This is the Red histogram front end peak.

Appendix E: Image Analysis Results

Please see attached.

Appendix F: Cost Analysis Sheets

Image Analysis Package:

Purpose:

- A uniform method of quality control is achieved with the image analysis package.

Components:

Component	**Cost**
3.2 MP Hewlitt Packard digital camera. (www.staples.com)	$150
18"X12" Digital Pursuits camera stand. (www.bugeyedigital.com)	$60
MatLab featuring Image Processing Package. (www.mathworks.com)	$2669

Description:

- The digital camera is mounted to the camera stand. Photos taken with the camera are then processed in the image processing feature in MatLab.

Total Cost: $ 2879

Cleated Belt Conveyor:

Purpose:

- The conveyance of raw coconut flakes to cooker/blender with minimal damage to material.

Components:	Cost
• Kamflex® Quick-Ship Series 811 (www.kamflex.com)	$10,520

Description:

- Stainless steel conveyor with cleated, molded plastic belting with an overall length of 12 ft and belt width of 12 in. This item features an infeed hopper for loading of material. Also included are cleanout ports to assist in sanitation and maintenance.

Total Cost:	**$10,520**

V- Blender with Spray Bar:

Purpose:

- Cooking and sweetening of the coconut flakes.

Components:	Cost
• Patterson Kelley V Blender (www.patkelco.com)	$120,000

Description:

- Stainless steel 20 cubic feet V- blender with low shear high intensity bar.

Total Cost:	**$120,000**

Palm Tree Processing

Coconut Sweetening Process

Elizabeth Casey
Justin Dillingham
Mohd Hussain
Brady Stewart

BAE 4022 – Spring 2006

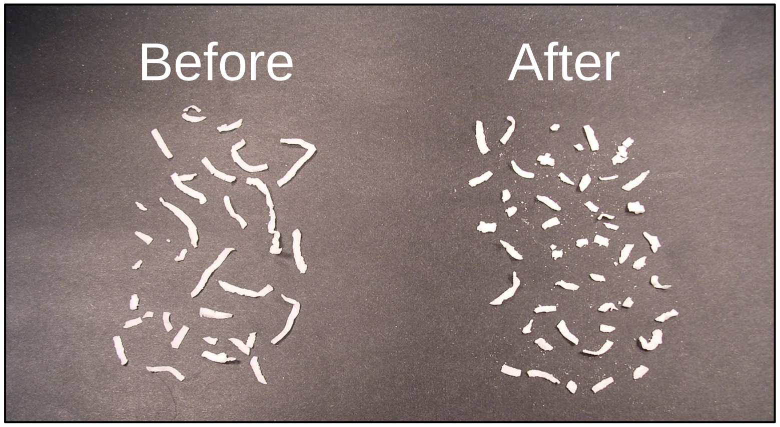
About Griffin Food Company

- Founded in Muskogee, OK in 1908 by John T. Griffin
- Major products available:
  - Syrups
  - Jellies and preserves
  - Mustards
  - Coconut flakes

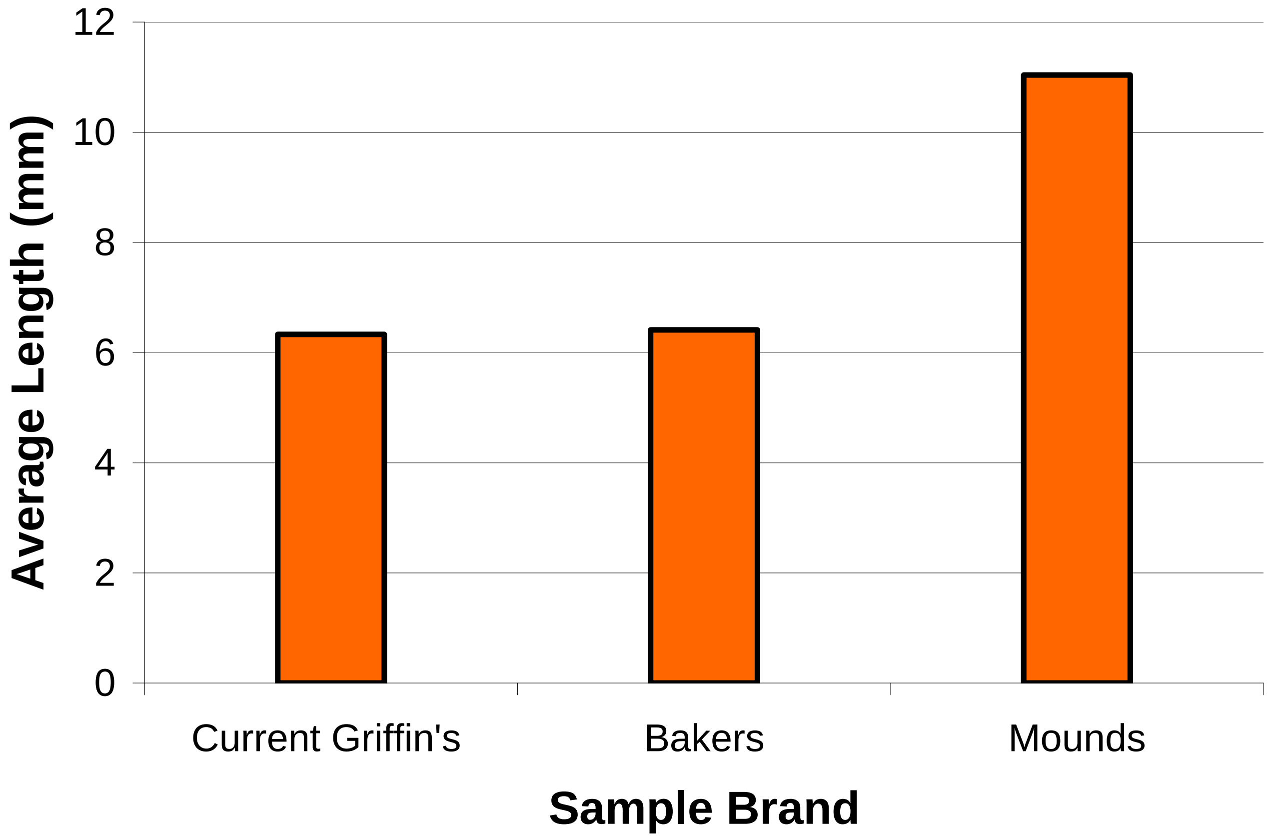
Problem Definition

- Consumers demand the longest length of coconut flakes possible

- Flake length of Griffin's coconut degrades during processing



Competitor Length Comparison



Project Goals

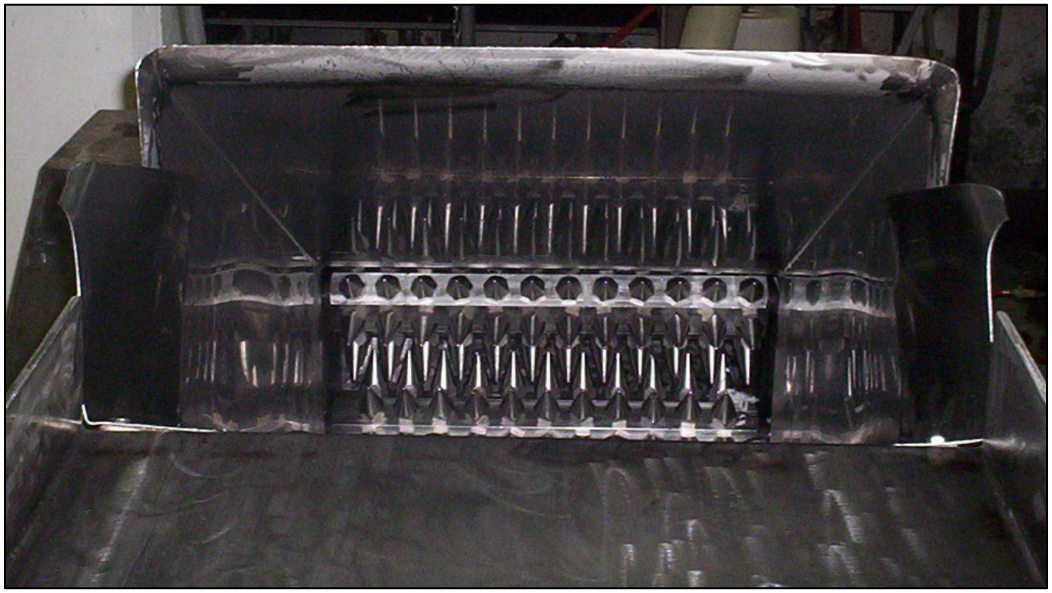
- Pinpoint and quantify degradation
- Make recommendations to:
  - Prevent flake length degradation
  - Increase processing capacity
  - Improve quality of work for employees

Process Steps

- Delumping
- Conveying to cooker
- Cooking and blending
- Tempering
- Packaging

Delumping

- Clumps of coconut form during storage
- Delumper used to separate clumps



Conveying to Cooker

- Auger transports coconut from delumper to cooker
  - Contained within PVC pipe
- Frequently clogs
- Limits processing speed

Palm Tree Processing

Cooking and Blending

- Double ribbon agitation cooker
- Blends slurry, sugar and coconut
- Runs continuously during delumping and conveying

Concept Development

- Quantifying coconut flake length
  - Modified ASAE Standard S424
  - Image Analysis with MatLab
- Potential Solutions
  - Proposal A – Steam Injection
  - Proposal B – Replacement of Auger Conveyor
  - Proposal C – Replacement of Cooker

Image Analysis with MatLab

- Setup camera system
- Prepare sample
  - Separate overlapping material
- Capture image

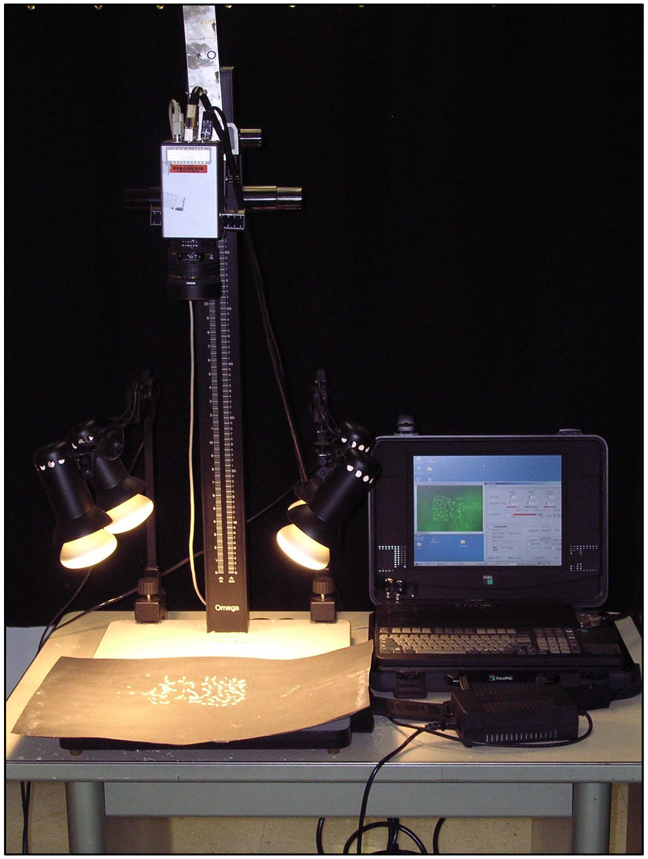
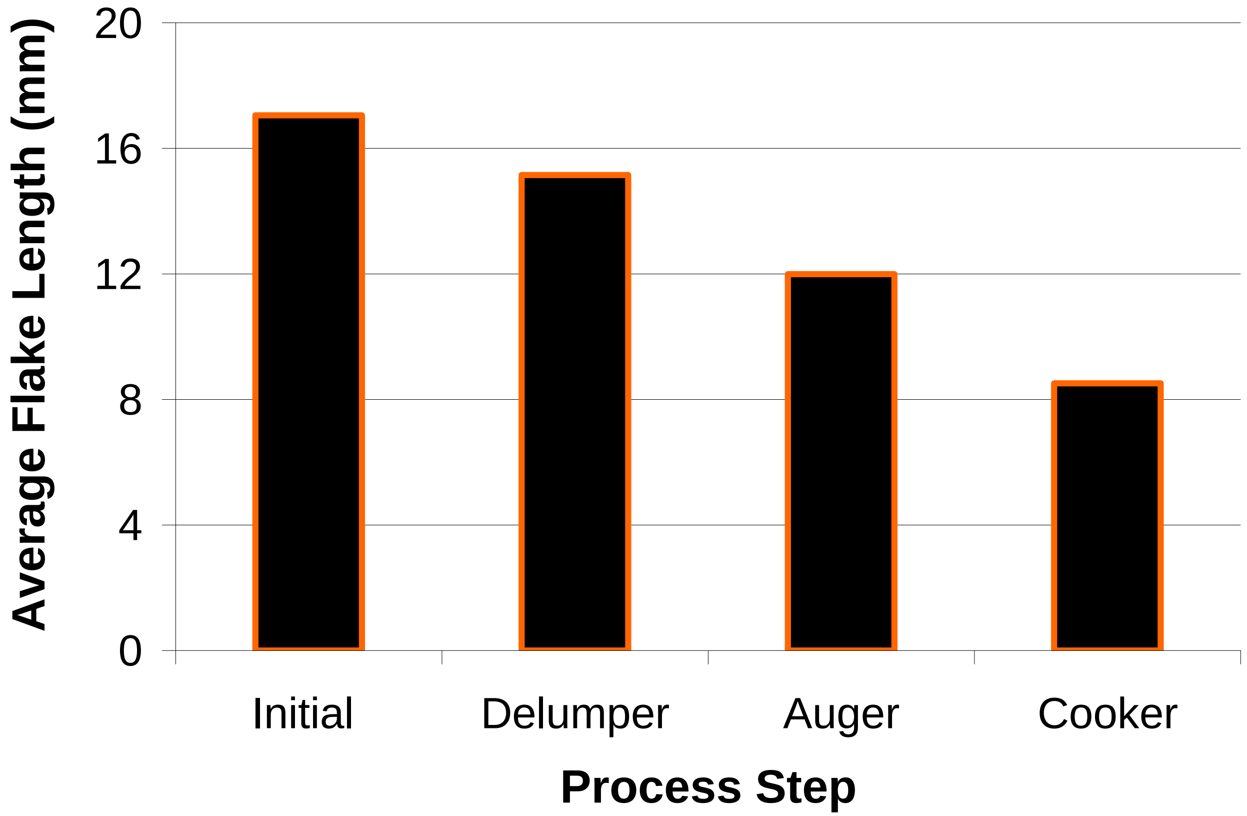


Image Analysis with MatLab

- Process image in MatLab
- Input data into Excel
  - Calculates average length

$$\text{Average Flake Length} = \frac{\text{area from MatLab} \times \text{actual picture area}}{122.97 \times \#\ \text{of strands} \times \text{MatLab picture area}}$$

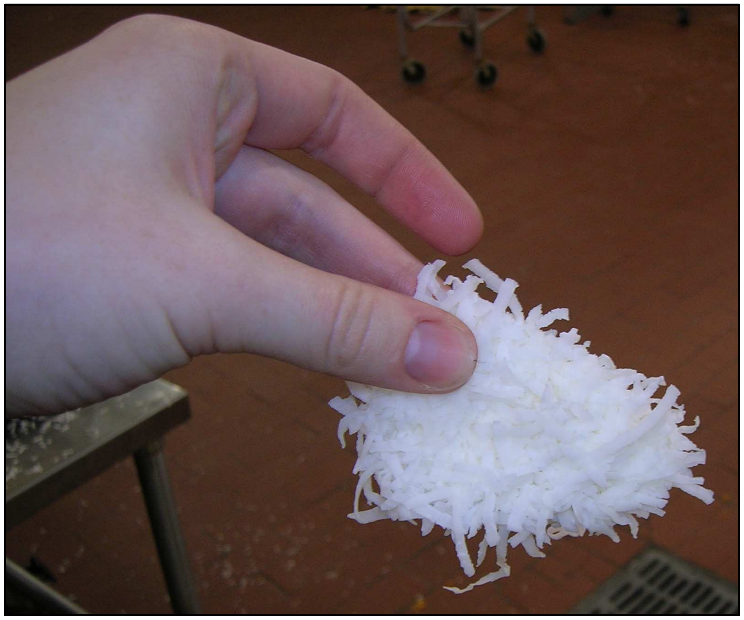
Results



Average Flake Length (mm)
20
16
12
8
4
0
Initial
Delumper
Auger
Cooker
Process Step

Proposal A – Steam Injection

- Researched direct steam injection systems
- FAPC testing
  - Steam table
- Did not meet project goals



Proposal B – Replacement of Auger Conveyor

- Inclined flighted belt conveyor most suitable
  - Requires half as much power as auger conveyor
  - Increases capacity
  - Extremely gentle on product

www.kamflex.com

Proposal C – Replacement of Cooker

- Focused on tumble blenders
- FAPC testing
  - 8 L V-blender
- Patterson Kelley testing
  - 8 L V-blender with intensifier bar

Proposal C – Replacement of Cooker

Type of Blender	Percent Degradation
Griffin's Ribbon Cooker	29%
FAPC V Blender – Test 1	10%
FAPC V Blender – Test 2	34%
Patterson Kelley V Blender – Test 1	9%
Patterson Kelley V Blender – Test 2	6%

Evaluating Proposals

- Potential length improvement
- Ease of transition
- Cost

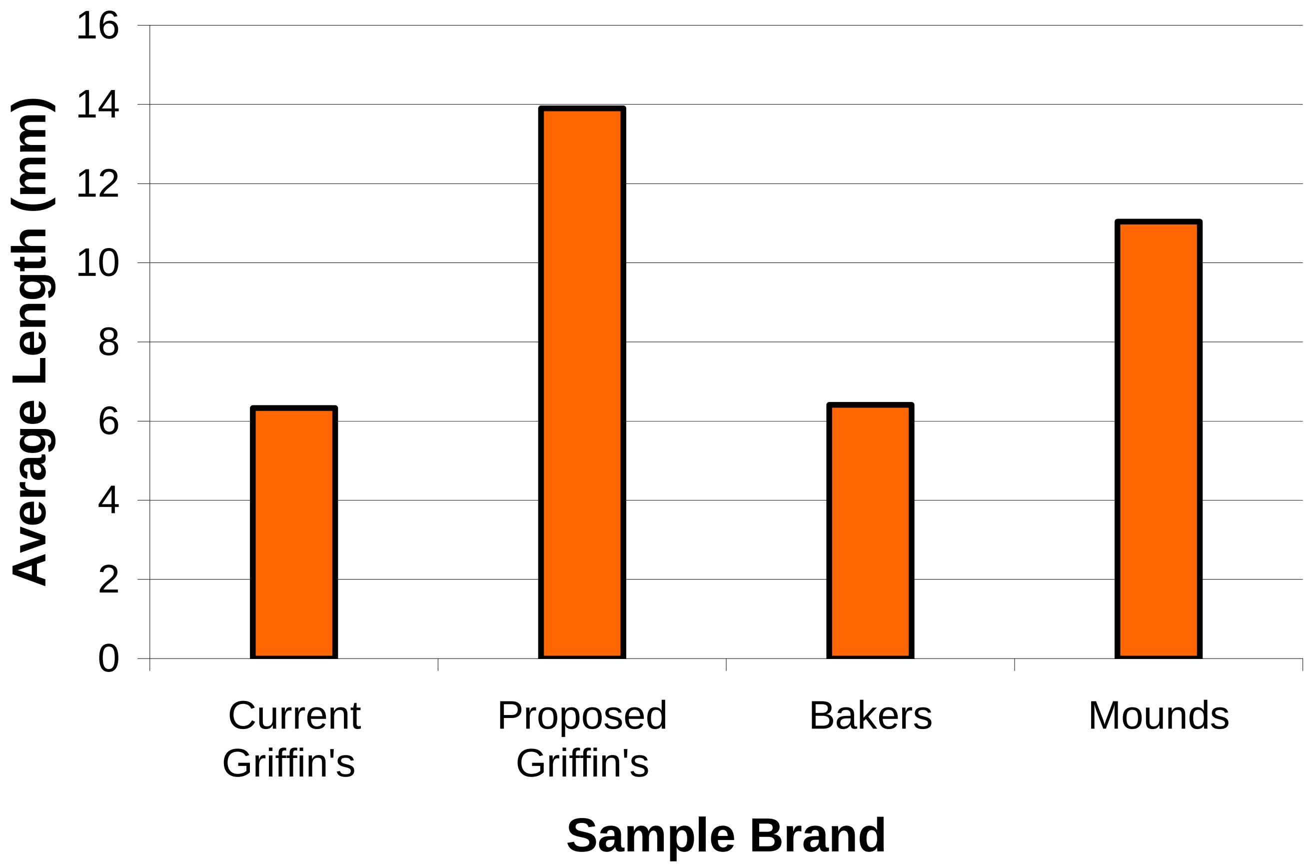
Cost Analysis

Equipment	New Cost	Used Cost
Image Analysis Package	$2,879	---
Cleated Belt Conveyor	$10,520	$5,000
V-Blender with intensifier bar	$120,000	$25,000

Final Recommendations

- Image analysis package
  - To monitor length quality
- Kamflex Series 811 Cleated Belt Conveyor
- Patterson Kelley 20 ft^3 V-blender with intensifier bar

Projected Length Improvement



Palm Tree Processing

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- Richard Hall
- Craig Duncan
- David Clary
- John Trammel

BAE Faculty and Staff

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- Dr. Gerald Brusewitz
- Dr. Tim Bowser
- Roshani Jayasekara

Palm Tree Processing

Coconut Sweetening Process

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Mohd Hussain
Brady Stewart

BAE 4012 - Senior Design
December 9, 2005

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Table of Figures

Introduction

Sweetened coconut flakes are a popular confectionary product used in a broad array of foods. Coconut flakes can enhance various food properties such as texture, flavor and visual appeal. Griffin Foods is one of many companies that sweeten and package desiccated coconut flakes for placement into the retail marketplace. A bag of their coconut is pictured in Figure 1.

Figure 1. Griffin's Coconut Flakes

Problem Definition

Many consumers demand the longest length of coconut flakes possible. Griffin Foods has noted a decrease in its flake length after processing as seen in Figure 2. When compared to competitors such as Baker's and Mounds, the coconut Griffin's produces is noticeably shorter. The major distributor of Griffin's coconut flakes prefers the sweet flavor of Griffin's but desires the length of the leading competitors. The Palm Tree Processing consulting group is working with Griffin's to improve the length of their coconut flakes.

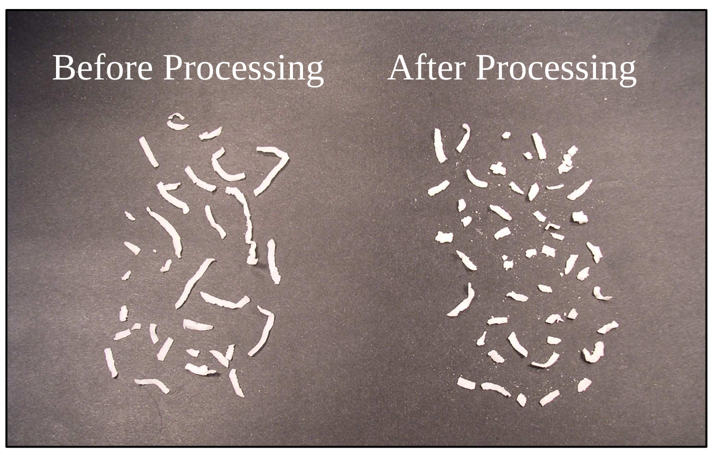


Figure 2. Flake Length Before and After Degradation

Statement of Work

Introduction

Griffin Foods is a family owned and operated business dedicated to providing consumers with the highest quality food products available. During sweetening of their coconut product, Griffin's notes a decrease in flake length. Degradation of coconut length may occur during any of five process steps: delumping, conveyance to cooker, cooking and agitating, overnight tempering and packaging. Palm Tree Processing will examine each of these process steps to determine where and to what extent flake length degradation occurs.

After visiting with various Griffin Foods employees, the team better understood the objectives and limitations of the project. At the completion of the project, the team hopes to make suggestions or recommendations on alternative process equipment or methods. These recommendations should improve final product length, processing capacity and quality of work for employees.

Process Steps

Delumping

Pre-shredded desiccated coconut is supplied to Griffin Foods in fifty pound bags. The coconut in these bags often hardens during storage, forming large clumps. Each bag of coconut passes through a delumper comprised of rotating spikes to separate these clumps. Griffin Foods employees designed and built the delumper shown in Figure 3. This unique design makes it difficult to modify or replace.

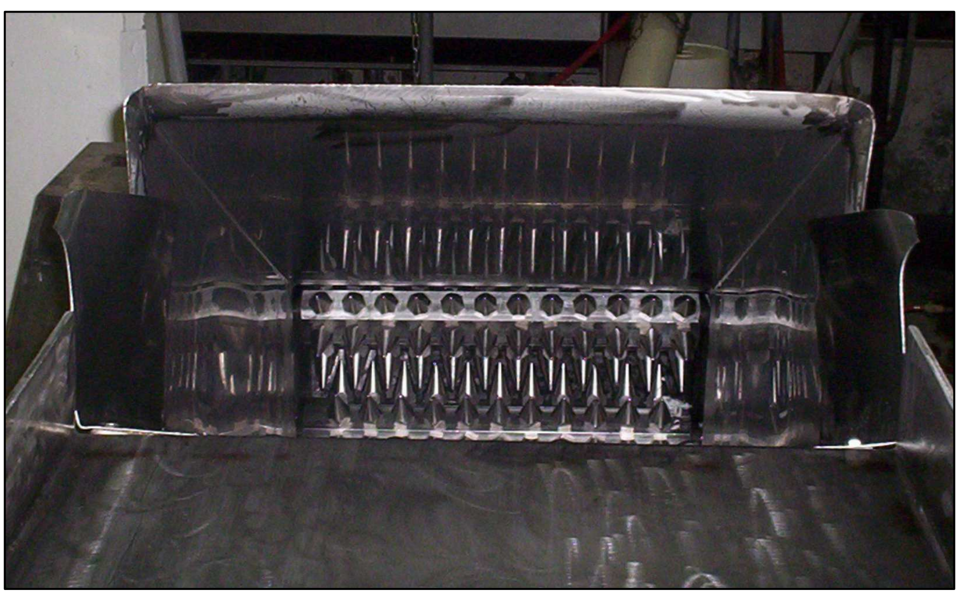


Figure 3. Delumper

Conveyance to Cooker

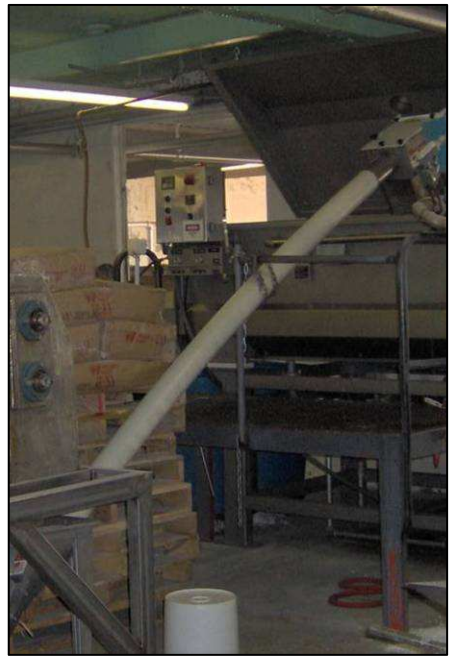


Figure 4. Auger Conveyor

The next step in processing is conveyance of coconut flakes to the cooker by use of an auger contained within a PVC pipe as shown in Figure 4. To maintain current production capabilities, the conveyor must operate at a speed of at least 30 hertz. This conveyor carries the coconut uphill, limiting the selection of possible replacements. For example, a conveyor belt with considerable slope may cause coconut flakes to slip. Initial observations show that this step may cause a decrease in flake length. It also increases production time because of frequent clogging of the conveyor.

Griffin's employees believe that the longer the coconut spends in the cooker, the more degradation the product undergoes due to the rotating ribbon agitators. These agitators operate continuously as the coconut is conveyed and fed into the cooker. Minimizing the time spent conveying the coconut will minimize the time spent in the cooker.

Cooking and Blending


Figure 5. Double Ribbon Agitation Cooker

Griffin Foods currently uses an agitation-type cooker similar to the one shown in Figure 5. Two ribbons rotate in opposite directions ensuring blending of the coconut with the slurry. The direct agitation of the ribbons may cause product degradation as flaked coconut grinds against the sides of the cooker. Agitation occurs throughout the entire conveying process and during cooking.

Shortening the time spent in the agitation-type cooker may help improve final product length. Griffin's employees discovered that other coconut processing facilities use a tumbler blender and experience less product degradation. If the cooker is replaced, its capacity must meet or exceed the current batch size of 1800 pounds.

Tempering

After cooking, the batch of coconut is emptied into barrels for overnight tempering as shown in Figure 6. This ensures uniform moisture distribution throughout the product. No apparent product degradation occurs during tempering, however, clumps may form due to the sugar and moisture added from cooking. These large clumps must be separated before packaging.

Figure 6. Tempering Barrels

Packaging

Packaging begins by unloading the barrels into another auger conveyor. This step requires extensive manual labor because of the clumps formed during tempering as seen in Figure 7. Employees use small paddles to empty the barrels. This may lead to increased product degradation. The conveyor frequently clogs with the processed coconut, thereby stopping the entire packaging process. After the conveyor, the product passes through a second delumper into the packaging machine. The team can only modify the conveyor portion of this process.

Figure 7. Unloading the Barrel for Packaging

Investigation

Properties of Desiccated Coconut

Griffin Foods uses desiccated coconut from the Philippines to produce their sweetened coconut flakes. According to Woodroof (1970), desiccated coconut is usually prepared by shredding the coconut meat and drying it to a moisture of 2-5 %. Pneumatic conveyors send the dried coconut to packaging. After packaging, the bags are stored until shipment. Coconut strands, averaging 1/16 inch in width, often lose palatability and tenderness after prolonged storage or microorganism contamination. Minimizing storage time before shipment and processing should reduce this deterioration.

According to research done by Reginald Child (1964), desiccated coconut should be pure white in color and crisp with a fresh taste. The coconut should contain between 68-72 % oil and less than 0.1 % free fatty acid. During shipping, the coconut temperature should remain below

35°C or the coconut may exude oil, leading to staining of the product and increased probability of spoilage. Griffin's should attempt to store the coconut below this temperature.

Sweetening and Rehydration Process of Desiccated Coconut

Most American companies use coconut from overseas. This coconut is dried to below 5% moisture content for shipping. Unfortunately, low moisture content flakes have a low quality taste and texture. To improve the quality, moisture is incorporated back into the product. The addition of only water can actually decrease the final product quality by producing a matted texture and off-flavor. The use of humectants, such as creamed coconut, may prevent these problems.

Patent 4363825, submitted by General Foods Corporation (1981), describes one of the various ways to rehydrate and sweeten coconut flakes intended for bakery and/or confectionary purposes. During shipping and storage, flakes compact together and may form chunks or bricks of coconut. General Foods first step in creating high quality sweetened coconut separates these chunks by steaming the bag for up to 60 seconds. The coconut remains in its original shipping bag both during steaming and the dead time before the next step. Following steaming, General Foods dumps the coconut flakes from the shipping bag into a churn rotating between 10 to 14 rpms. Once at 65°C, they spray the creamed coconut and propylene glycol solution onto the coconut flakes. Spraying should last between 2 to 8 minutes, preferably at most 5 minutes. After coating the flakes with liquid, powdered sugar is sprayed onto the coconut for 4 to 6 minutes. This mixture churns for up to 5 more minutes. Removing the coconut flakes from the churn and placing them into a stainless steel container for up to 170 hours before packaging ensures uniform distribution of moisture.

Woodroof (1970) describes another method to rehydrate desiccated coconut. The process begins by loosening the coconut by injecting steam into the bags. Employees then place the coconut into a mixer where addition of the slurry occurs. Employees prepare the slurry by dissolving invert sugar in water and heating this mixture to 180°F. They run the mixer at low speed for 2-3 minutes, blending the desiccated coconut with the slurry. After mixing, the blended coconut and slurry sets for 15-30 minutes. This formula produces a cut of coconut with 11-12% moisture content.

The sweetening and rehydration process varies from business to business. Griffin Foods may incorporate some of the steps of these methods into their current process to improve their final product.

Classification and Measurement of Desiccated Coconut

Classification Standards

Numerous companies throughout the world produce grated desiccated coconut. Two standards exist for classifying coconut flakes by length: Codex Standard 177 and Thai Industrial Standard 320-2522.

Codex (2001) created a classification system for the commercialization of grated coconut. Codex Standard 177 specifies three types of coconut based on granulometry: extra-fine, fine or medium. Appendix A contains this standard in its entirety.

Standard 320-2522, developed by Thai Industrial (1979), specifies grades, marking, sampling and other criteria for classifying desiccated coconut. They developed 5 grades on the basis of particle size: coarse, medium, fine, super fine and fancy. This standard is located in Appendix B.

This project requires calculating the average length of coconut flakes. Little information is available regarding the measurement of shredded coconut length. The methods described in the two standards for classification may be modified to determine an average flake length.

Measurement Methods

The American Society of Agricultural Engineers (1988) developed a standard which includes a step by step process for determining particle size of chopped material by screening, see Appendix C. ASAE designed this standard to measure the average length of chopped forage materials. The team may modify this standard to apply it to shredded coconut.

The standardized method involves the screening of particles through sieves. The sieves are stacked vertically with the largest apertures being at the top and the smallest at the bottom. The sieves are filled with the material to be tested, and then oscillated at a certain frequency to sift the particles through the screens. After sifting, the weight in each sieve is measured. Using the weight and the corresponding sieve size in a standardized logarithmic equation, Equation 1, average particle size is calculated.

$$X_{gm} = \log^{-1}\left[\frac{\sum\left(M_i \log \overline{X_i}\right)}{\sum M_i}\right] \qquad \textbf{[Equation 1]}$$

where X_{gm} = geometric mean length

$\overline{X_i}$ = geometric mean length of particles on i^{th} screen

M_i = mass on i^{th} screen

Cross checking the results from this method against an individual measurement of each particle within the sample could verify the accuracy of this method for determining average coconut strand length. This standard could pinpoint where length degradation occurs by comparing the average particle size after each process step.

Few methods exist for measuring the length of shredded or flaked materials. The Journal of Food Engineering (2004) describes an experimental method for measuring the length of shredded cheese through image analysis. This method could be modified for use with flaked coconut.

Design Criteria

Griffin Foods provided the team with specific requirements to consider while researching and developing potential solutions for the improvement of coconut flake length. These requirements must be met in order to satisfy Griffin's needs.

One such requirement is that their recipe may not change. Current consumers prefer the sweet flavor of Griffin's coconut product when compared to leading competitors. Any alteration of the recipe may change this desired flavor and/or the physical properties of the coconut.

Any change in process steps must meet or exceed the current production capacity. It currently takes approximately 12 hours to complete a day's worth of processing. If the capacity decreases, this time could potentially increase. This would cause labor costs to also increase while the quantity of product remains the same.

Another requirement is that any recommendation must easily fit into Griffin's current production line. This should allow for an easy transition from the existing line to the improved line. Construction time of the improved line should be minimized to prevent potential downtime.

Coconut production is a minor part of Griffin Foods operations. Griffin's has minimal funds available for any potential improvements. Therefore, Palm Tree Processing must take cost into consideration when evaluating potential solutions and making final recommendations.

Concept Development

Before developing potential recommendations, the team must determine where and to what extent flake length degradation occurs. This requires a method of quantifying flaked coconut length to find the average flake length after each process step. The team will compare lengths before and after each process step. The percent degradation for each step will then be calculated using Equation 2.

$$P = \left(\frac{X_n - X_{n-1}}{X_n} \right) * 100\% \qquad \textbf{[Equation 2]}$$

where P = Percent degradation

X_n = Average length of n^{th} process step

X_{n-1} = Average length of previous process step

To achieve the most effective results, the team will base its recommendations on the step(s) with the highest calculated percent degradation(s).

Sample Testing

Palm Tree Processing found two methods regarding measurement of the length of shredded or flaked material. The team will evaluate each method and base its recommendations on the best of the two.

Procedures

ASAE Standard S424 (1988) describes one such method. The team modified this standard for use with coconut flakes. The testing procedures are as follows:

- Weigh 255 mL of sample and record
- Align 5 sieves in decreasing size, see Figure 8
    - 9.5 mm
    - 6.3 mm
    - 4.75 mm
    - 3.35 mm
    - 2 mm
- Shake sieve manually for approximately 15 seconds
- Remove each sieve carefully and weigh contents
- Calculate geometric mean length using Equation 1
- Calculate percent degradation using Equation 2
- Repeat for each sample

Figure 8. Sieve Setup

The team created a modified version of the method described in The Journal of Food Engineering (2004) to determine the average flake length of coconut. The testing procedures are as follows:

- Setup 3-bandwidth camera as shown in Figure 9
- Spread coconut sample evenly on black construction paper, careful to avoid overlapping
- Record length between camera and paper
- Capture image of coconut sample as a '.tif' file
- Use Mat Lab to analyze image and determine mean flake length in pixels
- Convert pixels to millimeters
- Calculate percent degradation using Equation 2
- Repeat for each sample

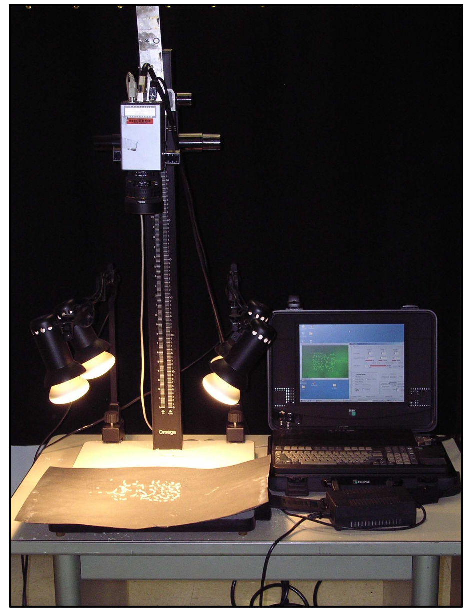


Figure 9. Camera Setup

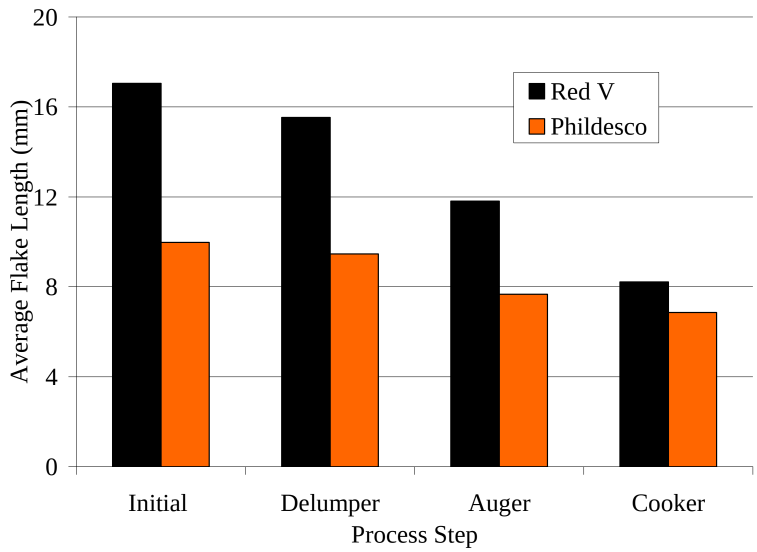
Results

Palm Tree Processing evaluated both measurement methods. The team tested several samples using the modified ASAE standard and obtained average flake lengths. To verify these results, the team measured a sample of flake lengths by hand. The average length calculated by the team was significantly greater than that calculated using the standard. This method also showed an increase in flake length during processing. Processing can only degrade flake length; therefore this method proved invalid for use with flaked coconut.

After failure of the modified ASAE standard, the team used image analysis with MatLab to determine average flake length. The team tested a set of samples with this method. The average flake length computed by MatLab was compared to that measured by hand. This comparison validified MatLab's calculations.

Finding this method successful, Palm Tree Processing tested the samples collected after each process step. The team found the average flake length after each step as shown in Chart 1. Phildesco and Red V results were kept separate because of the large difference in the initial average flake length.

Chart 1. Average Length of Coconut Flakes



Using Equation 2, the team calculated each step's percent degradation with these average lengths. The results for both Phildesco and Red V brands of coconut are provided in Table 1.

Table 1. Average Length and Percent Degradation of Coconut Flakes

	Phildesco		Red V	
Sample	Average Length (mm)	% Degradation	Average Length (mm)	% Degradation
Initial	9.98	0	17.05	0
Delumper	9.46	5.18	15.53	8.94
Auger	7.67	18.87	11.81	23.98
Cooker	6.86	10.62	8.22	30.41

The results show that average length degrades after each step of the process for both brands of coconut. Phildesco degrades the most during auger conveyance from the delumper to the cooker. Red V experiences the most degradation in the cooker. The overall degradation from the beginning to the end of the process for Red V was 51.8%, whereas Phildesco was only 31.2%. This difference may indicate that once coconut flakes reach a certain length minimal degradation occurs. Appendix D contains the raw data.

At the completion of testing and analysis, the team identified where and to what extent flake length degradation occurred. The team will base its recommendations on this information.

Potential Solutions

Proposal A - Steam Injection

Results showed that an average 26.9% degradation occurred from both the delumper and the auger conveyor. A steam injection process could possibly replace these steps. Injecting steam directly into a bag of coconut may separate clumps without the use of a mechanical device such as a delumper. After steam injection, the bag of coconut dumps directly into the blender/cooker, bypassing any need for conveyance. Much less handling of the coconut occurs with the steam injection process, reducing chances of flake length degradation.

Proposal B - Replacement of Auger Conveyor

Results showed 21.4% degradation of coconut flake length after auger conveying. The team has found two possible replacements for this conveyor.

Pneumatic Conveyor

A pneumatic conveyor could replace the current auger. This type of conveyor uses air to move materials such as chopped forage and grains of short to medium length. It has a variable capacity with a potential for high speeds. This conveyor type requires high power and low initial cost with easy maintenance and installation. A pneumatic conveyor exerts much less shear force on the materials it transports as compared to the auger conveyor. This could help prevent coconut length degradation.

Bucket Conveyor

A bucket conveyor could also replace the current auger conveyor. This conveyor utilizes buckets attached to either a chain or a belt to move free flowing materials such as grains, flakes or chips. Bucket conveyors have high capacities while efficiently and gently handling materials. The transported material remains virtually static in the bucket during conveyance. This could also help prevent coconut length degradation. However, a bucket conveyor can require extensive maintenance due to the large number of moving parts.

Proposal C - Replacement of Cooker with Tumble Blender

Results showed 20.5% degradation of coconut flake length after cooking and blending. A tumble blender could replace the agitation type cooker. This is essentially a chamber with a single agitation bar going through the center. This bar can add liquid ingredients as the chamber rotates, allowing gravitational forces to mix the components. This form of mixing produces a minimal amount of shear to the product, thereby preserving flake length. There are currently three tumble blender designs available: slant-cone, v-shaped and double-cone blenders.

Slant-cone

A slant-cone tumble blender consists of a cone-shaped chamber mounted at an angle to the ground as shown in Figure 10 (Gemco, 2004). This angle causes uniform blending due to the back and forth motion of the product during rotation. This design offers a very fast blend time with minimal blend variation. However, it requires a large headspace.

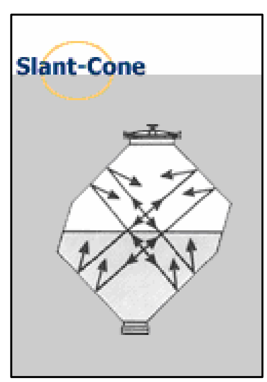


Figure 10. Slant-Cone Tumble Blender

V-Shaped

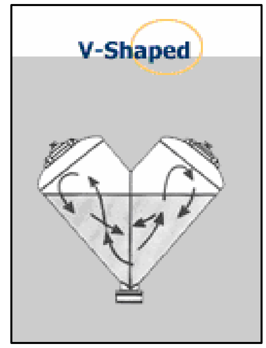


Figure 11. V-Shaped Tumble Blender

This blender consists of a V-shaped chamber seen in Figure 11 (Gemco, 2004). This shape causes the product to separate and intermesh continuously during rotation. The V-shaped tumble blender design offers very efficient blending, but is difficult to clean.

Double-Cone

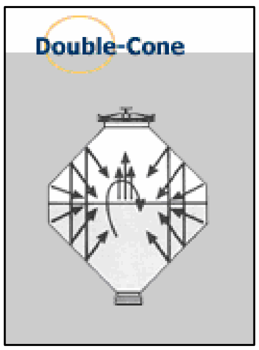


Figure 12. Double-Cone Tumble Blender

This blender consists of two cones that rotate around the support bar as shown in Figure 12 (Gemco, 2004). The compact design of the double-cone blender allows for greater blending volumes with minimal space requirements as compared to the other blender shapes. Due to decreased movement within the chamber, this shape requires longer blending time.

Project Schedule

Palm Tree Processing created a task list to guide the team throughout the fall and spring semesters. Using the task list, the team developed a Gantt chart. It is provided in Appendix F. It may be changed as the team feels necessary.

Conclusion

Palm Tree Processing has determined where improvements in the coconut sweetening process need to be made. The team will evaluate alternatives during the spring semester and make final recommendations to Griffin Foods.

References

ASAE Standards. 1988. S424: Method of Determining and Expressing Particle Size of Chopped Forage Materials by Screening. St. Joseph, Mich.: ASAE.

CODEX. 2001. CODEX Standard 177: Grated Desiccated Coconut. CODEX. Available at: www.codexalimentarius.net/web/standard_list.jsp. Accessed 25 October 2005.

Coker, G. C. 1981. Process for making a coconut product. U.S. Patent No. 4363825.

Child, R. 1964. *Coconuts*. 2nd ed. London: Longman Group Limited.

GEMCO. 2004. Principles of Tumble Blending. General Machine Company. Available at: www.okgemco.com/princ_tumblend/prince_blend.html. Accessed 05 November 2005.

Guanesekaran, S., and H. Ni. 2004. Image processing algorithm for cheese shred evaluation. *Journal of Food Engineering* 61(1): 37-45.

TIS. 1979. TIS 320-2522: Standard for Desiccated Coconut. Thai Industrial Standards. Available at: www.foodmarketexchange.com/datacenter/product/fruit/coconut/ detail/dc_pi_ft_coconut1102_0501.htm. Accessed 24 October 2005.

Woodroof, J. G. 1970. *Coconuts: Production, Processing, Products*. Westport, CT.: The AVI Publishing Company, Inc.

Appendix A: Codex Standard 177

Please see attached.

Appendix B: TIS 320-2522

Thai Industrial Standards TIS 320-2522 (1979) Standard for Desiccated Coconut

Date of Establishment: 2 November 1979
Date of Public Notice in the Government Gazette: 20 February 1980

In the event of any doubt or misunderstanding arising from this translation, the standard in Thai will be held to be authoritative.

1. Scope

1.1 This standard specifies grades, requirements, food additives, hygiene, container, weight and measure, marking and labeling, sampling and criteria for conformity for desiccated coconut.

2. Definition

For the purpose of this standard, the following definition applies:

2.1 DESICCATED COCONUT: The product obtained by drying the granulated or shredded white meat of the fully mature coconut kernel, Cocos nucifera Linn. by means of a mechanical air drying.

3. Grades

Desiccated coconut shall be of 5 grades when classified on the basis of article sizes by means of mechanical sifting.

3.1 Coarse shall be as follows.
- 3.1.1 Particle size: 3.35 mm to 4.76 mm, not more than 15% by weight
- 3.1.2 Particle size: 2.00 mm to 3.35 mm, not less than 70$ by weigh
- 3.1.3 Particle size: less than 1.AU mm, not more than 2.5$ by weight

3.2 Medium shall be as follows.
- 3.2.1 Particle size: 2.00 mm. to 2.80 mm, not more than 15% by weight
- 3.2.2 Particle size: 1.40 mm to 2.00 mm, not less than 70% by weight
- 3.2.3 Particle size: less than 1.00 mm, not more than 2.5% by weight

3.3 Fine shall be of 1.40 mm to 1.68 mm, not more than 15% by weight.

3.4 Super fine shall be of less than 1.00 mm.

3.5 Fancy type shall be of the bigger size and of the shape different from those specified in clauses 3.1 to 3.4.

Remark: The sieve aperture size in mm is equivalent to B.S. mesh No. as given in the table below.

The sieve aperture sizemm	B.S. meshNo.
1.00	16
1.40	12
1.68	10
2.00	8
2.80	6
3.35	5
4.76	-

4. Requirements

4.1 General requirements
Desiccated coconut shall be natural white, crisp and sweet having natural taste of coconut. It shall be free from rancidity, musty or other objectionable odour, insect infestation, fungus and foreign matter.

4.2 Parings The brown specks due to parings in coarse or medium grades shall not exceed 10 particles per 100 g when tested by the method prescribed in clause 10.2.

4.3 Colour The colour of desiccated coconut shall not be deeper than 0.2 Red, 0.7 Ye11ow and 0.1 Blue on the Lovibond tintometer scale for all grades when determined by the method prescribed in clause 10.3.

4.4 Bacterial contamination 4.4.1 Desiccated coconut shall not contain bacteria of the Salmonella group in each 50 g of sample when tested by the method described in clause 10.4. 4.4.2 The coliform count shall not exceed 10/g when tested by the method described in clause 10.4.

4.5 Chemical requirements The product shall comely with the chemical requirements given in Table 1.

Table 1 Chemical requirements (clause 4.5)		
Item	**Requirement**	**Analysis as clause**
Moisture content, max. % by weight	3	10.5
Oil content, min. % by weight	60	10.6
Free fatty acid, aslauric acid, max. % by weight of extracted oil	0.3	10.7

5. Hygiene

5.1 The hygiene of product shall conform to TIS 34-1973, Standard for General Principles of Food Hygiene.

6. Container

The container shall be clean, strong, durable, hermetically sealed and free from undesirable odour.

7. Weight and measure

7.1 Net weight of each container shall not be less than that declared on the label.

8. Marking and labeling

8.1 The label shall conform to TIS 31-1973, Standard for General Principles of Labelling Industrial Products.

8.2 At least there shall be figures, letters or code indicating the following information clearly and legibly on each container.

(1) Name of the product "Desiccated coconut"
(2) Grade
(3) Net weight in SI unit
(4) Code or manufacturing date
(5) Name of manufacturer or factor or trade mark or name of packet or distributor
(6) Country of origin

8.3 Any person who manufactures the industrial products complying with this standard may use the standards Mark in connection with his products only after having received a license from the Industrial Product Standards Council.

9. Sampling and criteria for conformity

Unless otherwise agreed upon, the method of sampling shall be as follows.

9.1 Lot: The product of the same grade and manufactured at the same time.

9.2 Sampling

9.2.1 The product shall be drawn at random from the same lot and the number of containers to be selected shall comply with those specified in Table 2.

9.2.2 The order of containers to be drawn shall be in accordance with the following formula.

$$r = N/n$$

Where r = the order of sample to be drawn
N = lot size
n = sample size

Table 2 Sampling plan (clause 9.2.1)	
Lot size (N)Container	**Sample size (n)Container**
Less than 50	2
51 to 150	3
151 to 300	5
301 to 500	7
501 to 1000	8
1001 and above	9

9.3 Preparation of test samples.
With a pasteurized spoon, approximately equal quantity of the material shall be taken from each of the selected container till the quantity collected is at least 500 g; mixed together in pasteurized, air-tight container and pt at 5-10°C. When tested, the sample shall be divided into two parts, one for micro-organism analysis mid the other for chemical analysis.

9.4 Criteria for conformity
The lot shall be considered as conforming to this standard provided that the: test results on sample obtained from clause 9.3 meet all the requirements specified in clause

Appendix C: ASAE Standard S424

Please see attached.

Appendix D: Image Analysis Results

Please see attached.

Appendix E: Gantt Chart

Please see attached.

Palm Tree Processing

Coconut Sweetening Process

Elizabeth Casey

Justin Dillingham

Mohd Hussain

Brady Stewart

BAE 4012 – Fall 2005

Mission Statement

- Palm Tree Processing is a consulting group that strives to help family owned and operated food businesses achieve the highest quality food products available.

About Griffin Food Company

- Founded in Muskogee, OK in 1908 by John T. Griffin
- Major products available
  - Syrups
  - Jellies and preserves
  - Mustards
  - Coconut flakes

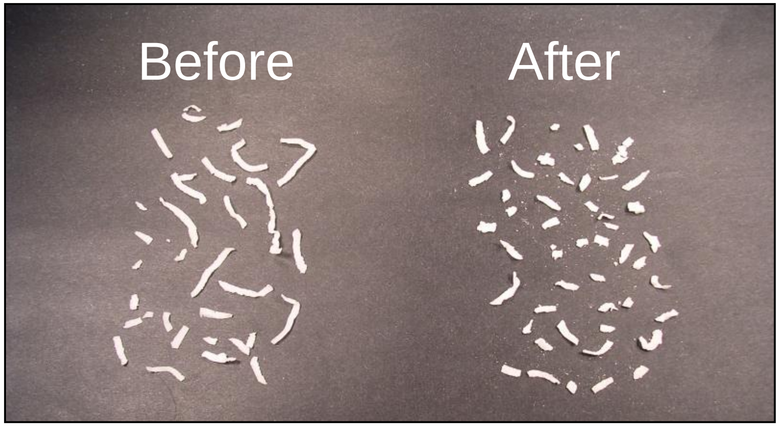
Griffin Food Company

Coconut Flakes

- Popular confectionary product
- Enhances food properties
  - Texture
  - Flavor
  - Visual appeal

Problem Definition

- Consumers demand the longest length of coconut flakes possible
- Flake length of Griffin's coconut degrades during processing



Project Goals

- Pinpoint and quantify degradation
- Make recommendations to:
  - Prevent flake length degradation
  - Increase processing capacity
  - Improve quality of work for employees

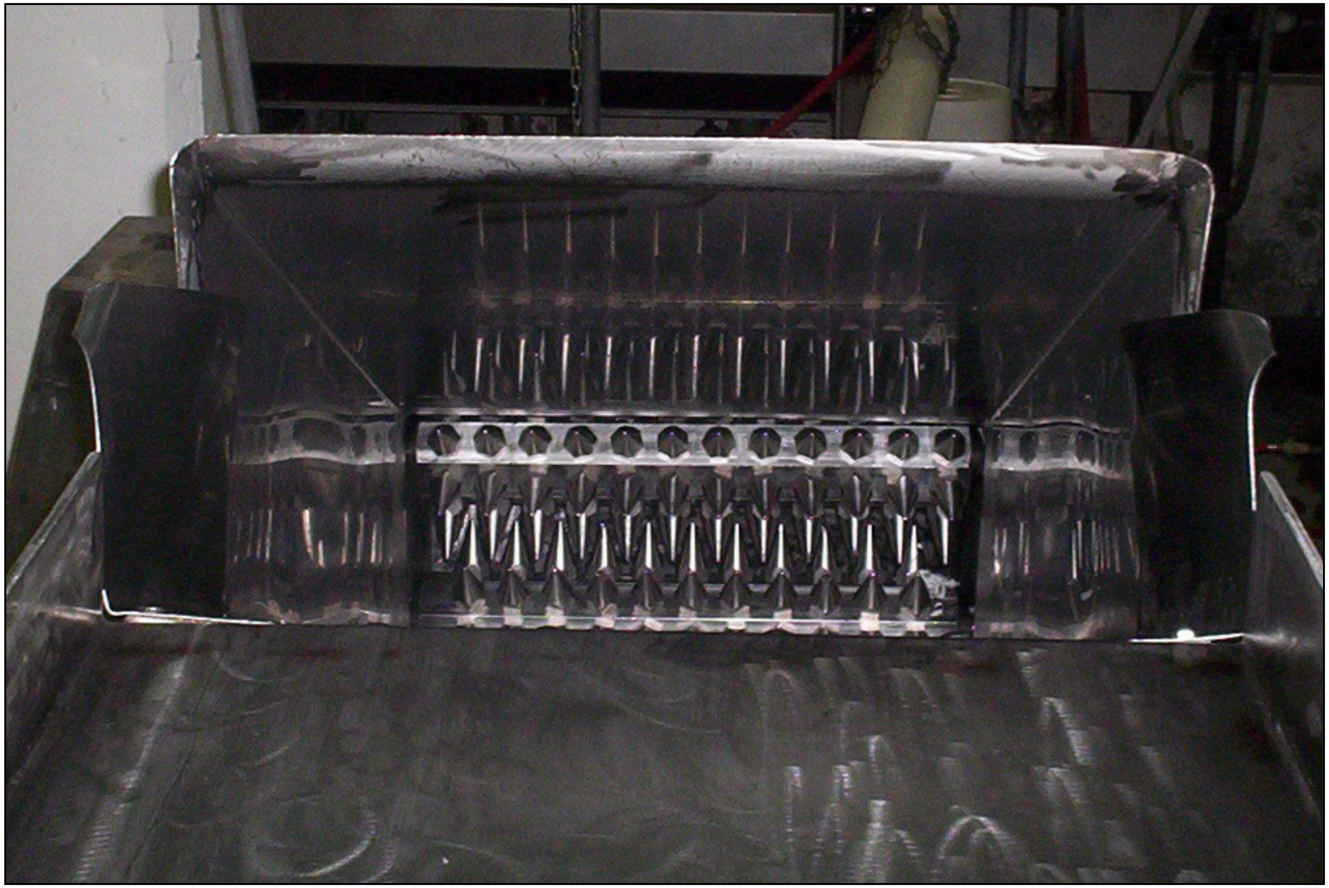
Process Steps

- Delumping
- Conveyance to cooker
- Cooking and blending
- Tempering
- Packaging

Delumping

- Clumps of coconut form during storage
- Delumper used to separate clumps
  - Rotating spikes
- Employee designed and built

Delumper



Palm Tree Processing

Conveyance to Cooker

- Auger transports coconut from delumper to cooker
  - Contained within PVC pipe
- Frequently clogs
- Limits processing speed

Cooking and Blending

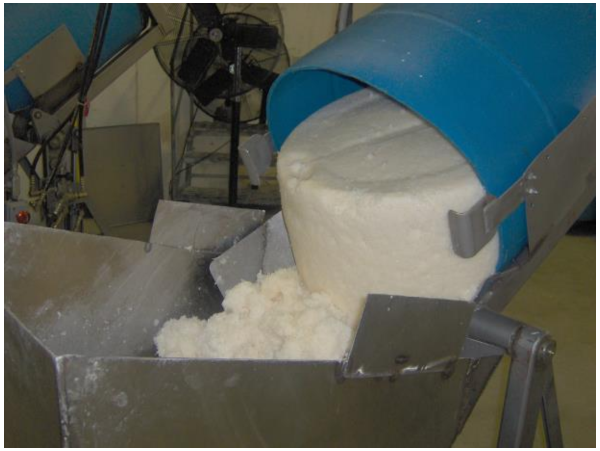
- Double ribbon agitation cooker
- Blends slurry, sugar and coconut
- Runs continuously during delumping and conveying

Tempering

- Barrels store coconut overnight
- Allows for uniform moisture distribution
- Large clumps often form

Packaging

- Barrels unloaded
  - Extensive manual labor required



- Auger conveys coconut to packaging machine
  - Frequently clogs

Design Criteria

- Recipe may not change
- Production capacity must not decrease
- Simple transition from existing to improved process line
- Minimal cost

Concept Development

- Quantifying coconut flake length
  - Modified ASAE Standard S424
  - Image Analysis with MatLab
- Potential Solutions
  - Proposal A – Steam Injection
  - Proposal B – Replacement of Auger Conveyor
  - Proposal C – Replacement of Cooker

Modified ASAE Standard S424

- Sieves separate coconut flakes
- Average geometric mean length calculated using:

$$X_{gm} = \log^{-1}\left[\frac{\sum\left(M_i \log \overline{X_i}\right)}{\sum M_i}\right]$$

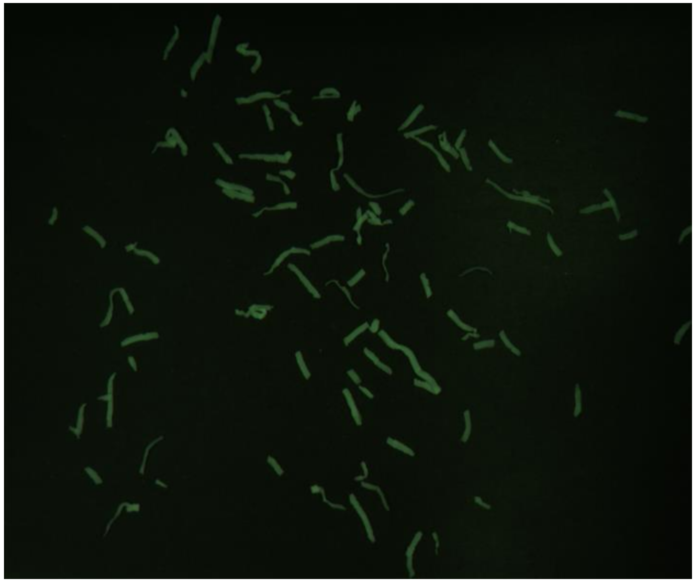
X_{gm} = geometric mean length

$\overline{X_i}$ = geometric mean length of particles on i^{th} screen

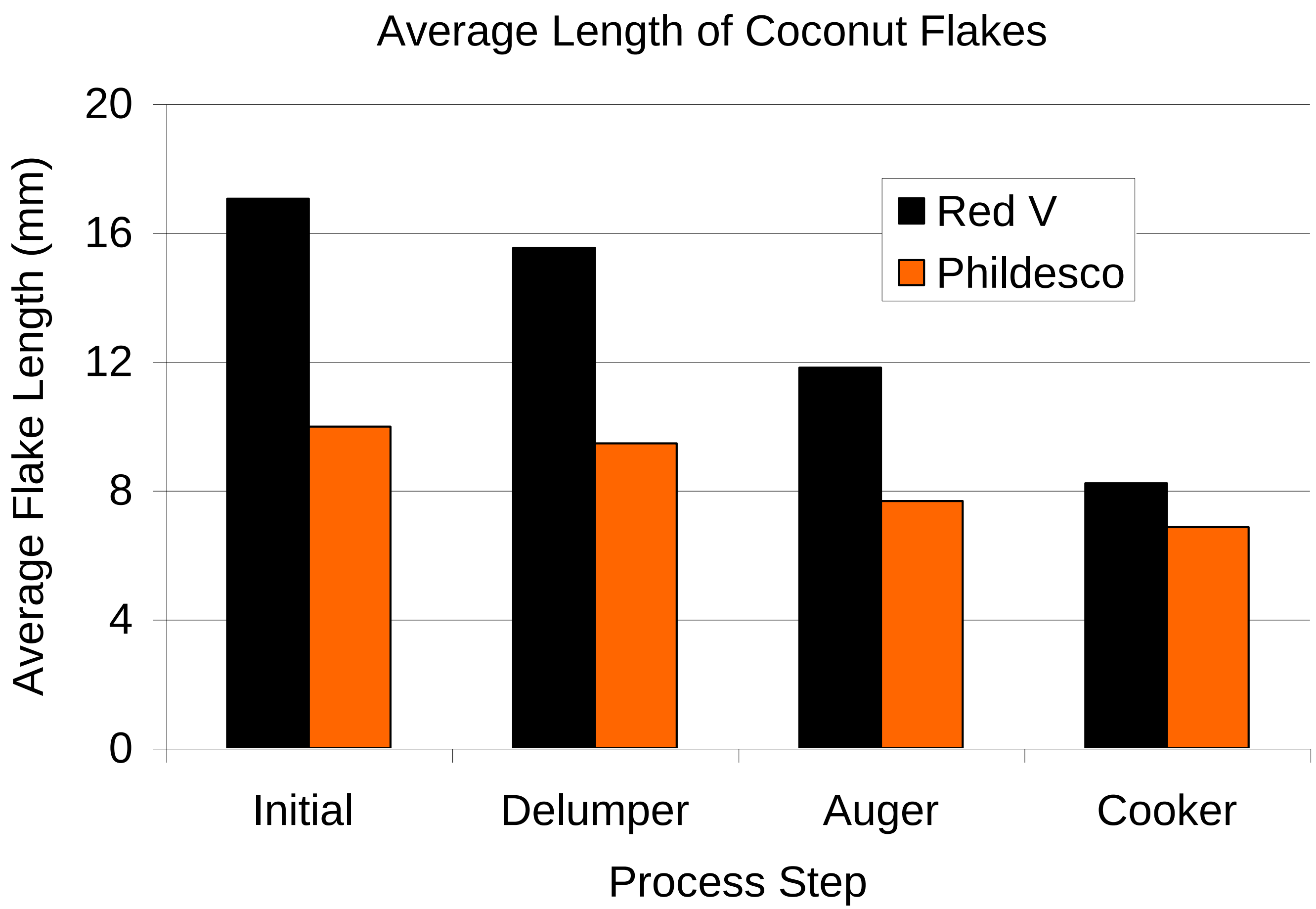
M_i = mass on i^{th} screen

Image Analysis with MatLab

- Picture taken of coconut flake sample
- Average flake length calculated with MatLab
  - Morphological Operations in Image Processing Package



Results


Average Length of Coconut Flakes
Average Flake Length (mm)
0
4
8
12
16
20
Red V
Phildesco
Initial
Delumper
Auger
Cooker
Process Step

Results

Sample	Phildesco % Degradation	Red V % Degradation
Initial	-	-
Delumper	5.18	8.94
Auger	18.87	23.98
Cooker	10.62	30.41

Proposal A – Steam Injection

- Steam injected into bags of coconut to break up clumps
- Replaces delumping and conveying process steps

- **Pros**
  - Less handling of coconut
- **Cons**
  - May change coconut properties

Proposal B – Replacement of Auger Conveyor

Pneumatic Conveyor

- Pressurized air moves coconut flakes
- **Pros**
  - High capacity
  - Minimal stress on product
- **Cons**
  - High power requirement

Bucket Conveyor

- Buckets carry coconut flakes
- **Pros**
  - High capacity
  - Gentle on product
- **Cons**
  - Maintenance

Proposal C – Replacement of Cooker

- Replaces cooker with tumble blender
  - Rotating chamber mixes ingredients
- Types of tumble blenders
  - Slant-Cone
  - V-Shaped
  - Double-Cone

Proposal C – Tumble Blenders

Slant-Cone

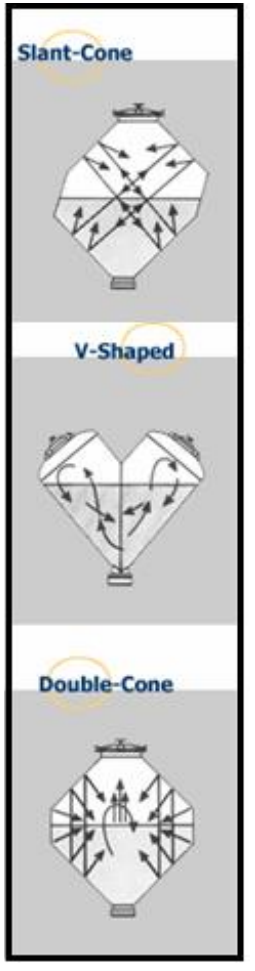
- **Pros:** Fast and uniform blending
- **Cons:** Requires large headspace

V-Shaped

- **Pros:** Efficient blending
- **Cons:** Difficult to clean

Double-Cone

- **Pros:** Minimal space requirements
- **Cons:** Longer blending time



Spring Schedule

- Continued development of flake length measurement methods
- Further investigation of proposals
- Evaluation and testing of proposals
- Final recommendations

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