Making Yacon Candy

Project Report
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Table of Contents

Abstract

Research was conducted to determine the feasibility of creating candy products from yacon syrup (a syrup produced from the storage roots of *Smallanthus sonchifolius*). Various formulations containing 72 °Brix yacon syrup and other minor ingredients (starches, dairy products, nuts) were tested in small batches using stovetop cooking methods. Several small-scale molding and packaging methods were also attempted. While concerns still remain over the stability of the candies over time, progress was made in creating candy products suitable for small-scale production. Preliminary consumer testing conducted within the International Potato Center (CIP) showed great potential for these products amongst a variety of age groups. However, much research is still needed to perfect the formulations as well as the molding and packaging steps.

Section 1: Introduction

I came to CIP as a three-month research volunteer just after graduating from North Carolina State University (U.S.A.) with B.S. degrees in Food Science and Poultry Science. As a student I had also had the opportunity to do internships within the North American food industry for Kraft Foods and General Mills. Given this background, and especially my experience in the confectionary division at Kraft, Dr. Hermann and I decided that I should use my time at CIP working on a yacon project.

Interest in the processing of the yacon root (*Smallanthus sonchifolius*), a native root crop from the Andes, has increased recently. The popularity of this root is partially due to the fact that the majority of the sugars within the root are oligofructans. Oligofructans are not absorbed well by the body and therefore provide the body with fewer calories than many other sweet foods. One promising product is syrup, a concentrate obtained from filtered root juice. This syrup offers consumers a method of sweetening their food without adding as many calories and offering other health benefits. While the syrup itself is an exciting new product, CIP is seeking to develop other even higher value products from the syrup. Producing candies from yacon syrup is one of the potential ways to expand the market for yacon. This report will discuss research to date on various candy formulations, materials used, and methods of production. The intention of this work was to create formulations and procedures for small-scale/cottage industry production within developing countries.

Section 2: Product Novelty, Concept and Application

There is currently no evidence of the production of yacon candy. Although the production of yacon and its processing into convenience products has expanded dramatically in recent years, my colleagues at CIP and I have not found references to the making of candy from yacon within the Andean countries, nor from countries to which yacon has been introduced in past decades (Brazil, China, Czech Republic, Japan, New Zealand, Taiwan). The purpose of this report is to put the innovative product concept and processing techniques described in this report into the

public domain. Readers are encouraged to make use of the proposed product concept and techniques for product development or commercial application, but are reminded that no intellectual property rights can be taken out on the findings or suggestions of this report.

This report proposes yacon candy as a potential novel food or nutraceutical product with unique properties. It is made of natural ingredients, and provided it is obtained from appropriately selected yacon varieties, has a reduced caloric value (about half that of conventional candy). Owing to the bifidogenic action of its high oligo-fructose content, yacon candy can be expected to contribute to improved bowel movement and gut health.

Yacon candy has a range of potential applications in reduced-calorie diets, as candy suited for diabetics and in the dietary treatment of constipation. It is important to note, however, that the generation of data allowing the food safety assessment of yacon candy was outside the scope of this project and that such an assessment, in accordance with local food law, may be needed before the product can be placed on the market.

Section 3: Overview of Candy Production

Candy making is a fairly simple process. In traditional candy production, a mixture of sugar, water, and possibly corn syrup are mixed together and boiled until sufficient water has been boiled out of the candy mass. Use of a thermometer and the cold water test (discussed further in Section 6) help the candy maker to determine when the desired moisture loss and therefore texture attributes have been achieved. The hot syrup is then cooled slightly by removing it from the heat source. As the candy cools, it transitions from a syrup consistency to a much more viscous, solidifying candy mass. Before this mass has completely cooled, the candy must be molded into shapes using hand or mechanized molding methods, cooled completely, and packaged.

Figure 1: Basic hard candy production process for yacon syrup based candy. Photos by Caitlin Boon.

In the yacon candy production discussed in this report, yacon syrup is the main ingredient, and sugar and corn syrups are not used. The use of only yacon syrup should reduce the caloric level of yacon candies versus regular sugar-based candies. However, the properties of the yacon syrup also create problems with the stability of the candy. Several ideas of how to resolve these issues will be discussed further in Sections 5, 7 and 9.

Section 4: Equipment Needed for Small Scale Processing

- Heating source and pot for cooking the syrup

  There are several options based on the size of the operation and the amount of capital available for the project. Production in this small-scale range can be as simple as preparation in a household pan on a gas burner or as complex as using a steam jacketed kettle with a vacuum pump. There are advantages and disadvantages to all of the options. A steam-jacketed kettle with a vacuum pump would be ideal, especially for hard candy production, as it can remove more water from the syrup mixture. However, this equipment is quite expensive and requires care to maintain it in good working order, while the basic pot on a gas or electric burner is very inexpensive and can still produce nice candy.

- Table for forming candy

  An easy to clean table surface that can be sprayed/coated with oil for easy release of solidifying candy is needed. A stainless steal, marble slab or similar surface would be ideal. When extremely small (500g) batches are made, a foil-lined tray can take the place of a table.

- Candy molds – several options exist and are listed below

  - Drop roller

    The drop roller, as pictured in Figure 1, can produce a relatively large amount of plain hard candy in only a few minutes. It consists of two rollers turned by a hand crank. The rollers contain multiple hollows that form the shape of the candy as the candy mass is fed through the machine. These wells can be made into many different shapes and can produce candies that are shaped on both sides rather than having a flat surface on the bottom.

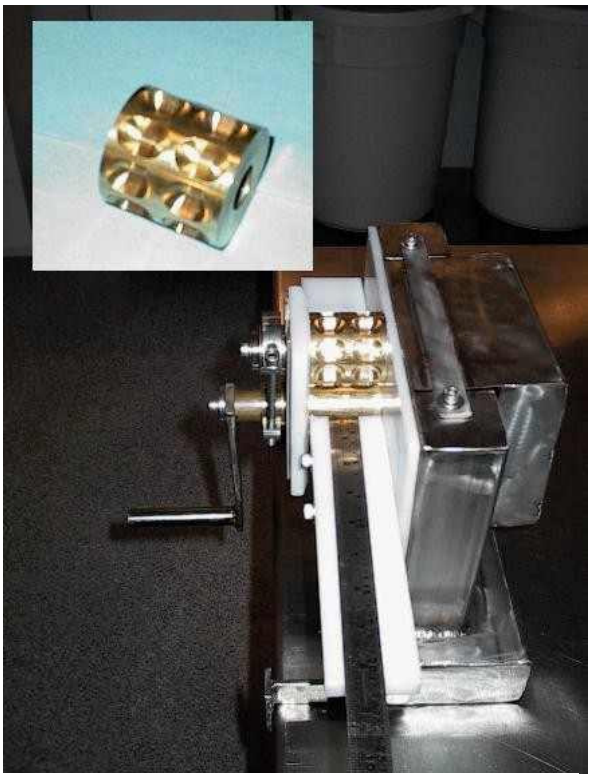

Figure 2: Drop roller. Photo provided by John Holland of J Holland Corporation

This equipment is fairly expensive. J. Holland Corporation, the only supplier found to date, charges a base amount of $3,750 per machine. This piece of equipment could only be used in the manufacture of plain hard candies – not caramels or nut-containing candies.

- Sheet molds

Plastic molds like the one pictured in Figure 2 are very inexpensive ($1-3) and made out of heat resistant, white plastic. However, during the course of this research we were not able to find these in Peru. Easy to find plastic molds for chocolate making will not work for hard candy as the syrup temperature is too high. In an attempt to avoid importing plastic molds, a stainless steel mold was fabricated during the course of this research. To date, it has not been possible to create a large quantity of nice looking candies using this mold. Much more work is needed to determine if this molding method is possible. These issues will be discussed further in the Special Concerns section.

Figure 3: Plastic mold. Photo by Caitlin Boon

- Knife & Cutting Board

By far the simplest method for forming candies is to cut the warm candy mass with a buttered/oiled knife. For this process a tray or long casserole dish is needed to pour the hot candy mass into. It is also useful to line this tray with heavy-duty aluminum foil for easy transfer of the candy mass to a cutting board where it is scored with a knife, allowed to cool, and broken into pieces.

- Thermometer

Figure 4: Using a digital thermometer to determine syrup temperature. Photo by Caitlin Boon

Thermometers can be useful tools in determining when specific ingredients should be added to various candy formulations and when the candy is at the desired texture stage. The cold water test (discussed in Section 6) can also be used to monitor these events, but it is not as accurate as many thermometers. When choosing a thermometer, make sure that it will be able to give accurate readings in the rapidly changing temperatures of the heating syrup. The best

thermometers are very expensive, so it is recommended that these thermometers be used in teaching the candy making process until new candy makers are comfortable with the cold water test method. A good thermometer is also critical as adjustments are being made in formulas and when other environmental factors are changing such as the altitude at which the candy is being produced.

- Protective equipment

  Candy making is a very hot and sometimes dangerous process. Proper equipment and care is essential to prevent accidental burns and cuts. Potholders and gloves are highly recommended when working with the hot candy. Even after the candy is cooled, care should be taken as hard candy is a glassy material and can easily cut those handling improperly formed pieces.

Section 5: Raw Ingredients

- Yacon Syrup

  Yacon syrup is created using an abrasive juicer to obtain yacon juice, and using maple syrup technology to concentrate it into a syrup. This syrup is high in oligo-fructans, which are hygroscopic, presenting several challenges to making candy that keeps its form and does not become sticky. Some of these issues may be overcome with the addition of other ingredients and with airtight packaging, which will be discussed further in other sections.

  All of the formulas tested in this research were made using 72°Brix syrup. If another °Brix syrup is used in these formulations, adjustments should be made in the formulation to account for the difference in solids content.

- Dairy Products

  Some of the formulas tested call for butter, dry milk, cream, or evaporated milk. These ingredients contribute both to the flavor and the texture of the candy. Addition of these products makes it easier to produce softer, chewy caramels and toffees that are difficult to make with syrup alone. Dairy ingredients tend to extend the period of time when the boiling candy mixture is in the hard ball and soft crack stages. Note that in formulations that call for cream or evaporated milk, one ingredient may be substituted for another with similar results.

- Starch

  Addition of starch has been found to greatly improve the stability of candies made from the yacon syrup, increasing the amount of time before the candies become sticky. Candies produced with starch were not as likely to become as sticky as those produced without starch. In addition, hard candies produced with starch were not as likely to become soft on the surface as those produced without starch.

  Several types of starch including corn starch, potato starch and achira starch were tested during this research. Corn starch was found to be the best starch for use in yacon candies as it produces a better texture. Candies made from

potato and achira starches had a sandy mouth feel that is most likely due to the large starch granule size of these starches (achira, or *Canna edulis*, has the largest starch granules known).

Starch must first be dispersed in a small amount of water before being added to the boiling candy mixture. It is essential to agitate the starch and water mixture just before adding it to the syrup as the starch settles quickly. To this point in research on these candies, 90°C appears to be a good temperature for starch addition. Candies produced with starch added at 90°C had fewer problems with softness, stickiness, and change in form than did candies produced when starch was added at a syrup temperature of 110°C. The 90°C temperature is also easy to identify even without a thermometer as it is arrived at just after the syrup comes to a complete and rapid boil. However, further testing could be conducted to determine if a different optimum temperature exists. It is recommended that further testing be conducted with starch concentrations between 4 and 8 percent of the total formulation.

Section 6: The Cold Water Test

Figure 5: Performing the cold water test. Photo by Caitlin Boon

By only looking at the boiling syrup, it is difficult to tell if enough water has been boiled out to create a suitable candy. If the temperature when certain textures are achieved is known, a thermometer is a great tool for deciding when the candy should be removed from the heating source. However, when the thermometer is not available, the cold water test is the best way to determine if the syrup is ready for cooling or forming. This test could prove especially useful in mountainous Peru as the temperature range of the texture stages is altered based on the altitude at which the candies are prepared.

To perform the Cold Water Test, all that is needed is a small container of cold water and a spoon. As the syrup cooks, small spoonfuls of syrup are poured into the cold water.

Table 1 lists the different candy stages for both sucrose (table sugar) and those experimentally determined for 72°Brix yacon syrup. The temperature ranges for sucrose are for producing candy at sea level. For every 500-foot (152 m) increase in altitude, 1°F (~0.56°C) should be subtracted from the temperatures listed (McGee, 412). The temperature ranges for the yacon syrup were experimentally determined in La Molina, which is at an altitude of 300 m. Had the sucrose ranges been determined in La Molina, they would have probably been slightly lower, although the difference would have been less than 1°F.

Table 1: Texture Stages and Temperatures for the Cold Water Test

Texture Stage	Temperature Range	
	Sucrose*	72 Brix Yacon Syrup
Soft Ball	112.8 - 115.5 C (235 - 240 F)	111 - 114 C (232 - 237 F)
Firm Ball	118.3 - 121.1 C (245 - 250 F)	115 - 119 C (239 - 246 F)
Hard Ball	121.1 - 129.4 C (250 - 265 F)	120 - 123 C (248 - 253 F)
Soft Crack	132 - 143 C (270 - 290 F)	**
Hard Crack	149 - 154 C (300 - 310 F)	126+ C (259+ F)

Definition of Stages as hot candy is dropped into the water:

Soft Ball: A small ball or clump forms, which is very soft and easily changes shape when touched or removed from the water.

Firm Ball: A small ball or clump forms, which is firm, but changes shape with little resistance when touched or removed from the water.

Hard Ball: A small ball or clump forms, which is hard, but changes shape with some resistance when touched or removed from the water.

Soft Crack: Threads of candy are created, which can withstand some bending before breaking.

Hard Crack: Brittle threads of candy are created, which break as soon as any pressure is applied in an attempt to bend the thread.

Other Notes on the Properties of the Yacon Syrup

- The 72°Brix yacon syrup was experimentally determined to come to a rapid boil in the 85 - 88°C (185 - 190°F) range.
- Once the hard crack stage is reached, the yacon syrup quickly begins to burn (within one to two minutes). Therefore, if hard candies are being made careful attention should be given to the syrup as it reaches this stage to ensure that the batch is not lost due to burning.
- The temperature ranges for the texture stages of the yacon syrup listed in Table 1 are those achieved when no additional ingredients are added. The addition of other

ingredients may alter the ranges some as well as lengthen the period of time that the syrup remains in a stage. For example, when dairy products such as cream or evaporated milk are used, the syrup can exhibit the properties of the soft crack stage for an extended period of time before the hard crack stage is achieved. When syrup alone is heated the soft crack stage is so brief that it appears as though the syrup transitions directly from the hard ball stage to the hard crack stage.

Section 7: Formulas and Processing Methods

Over 15 different formulas were tested during this project. Of these, seven were found to have enough stability for further testing. The other formulations produced candies that either became too sticky, too soft, or lost their form over time. All of the formulations have been included in this document for background to future research. They have been divided into two sections to differentiate the most promising formulas from the others. The formulas provided here are based on 500-gram batches. In addition, the percentage of each ingredient in the total formula is included so that the batch size can be easily altered.

Successful Formulas

Hard Candy with Corn Starch 2B

(g)	Ingredient	(% Total)
420.0	72 Brix Yacon Syrup	84.0
50.0	Water	10.0
30.0	Corn Starch	6.0

Hard Candy with Corn Starch 4B

(g)	Ingredient	(% Total)
430.0	72 Brix Yacon Syrup	86.0
50.0	Water	10.0
20.0	Corn Starch	4.0

Both of these hard candy formulas were made by bringing 72° Brix yacon syrup to a boil. The corn starch was dispersed in water and added to the mixture at 90°C. The syrup and corn starch mixture was cooked, stirring occasionally, until the syrup reached the hard crack stage.

Caramel with Corn Starch 2

(g)	Ingredient	(% Total)
340.0	72 Brix Yacon Syrup	68.0
40.0	Butter	8.0
40.0	Cream	8.0
50.0	Water	10.0
30.0	Corn Starch	6.0

Carmel with Corn Starch 4

(g)	Ingredient	(%Total)
355.0	72 Brix Yacon Syrup	71.0
40.0	Butter	8.0
40.0	Cream	8.0
50.0	Water	10.0
15.0	Corn Starch	3.0

Caramels were made by first adding butter and 72° Brix yacon syrup to a pot and bringing the mixture to a boil. The corn starch was dispersed in water and added to the mixture at 90°C, and the cream was added once the mixture reached 105°C. After cream addition, the mixture required constant stirring. The point at which to remove the mixture from the heat source depends on the targeted texture of the end product. In this research, Caramel 2 was removed from heat after the temperature reached 120°C (soft crack stage), producing a harder

caramel than that of Caramel 4, which was removed from heat at 114°C (firm ball stage), producing a very soft caramel.

Pecan Candy 1

(g)	Ingredient	(% Total)
335.0	72 Brix Yacon Syrup	67.0
25.0	Butter	5.0
50.0	Evaporated Milk	10.0
25.0	Water	5.0
15.0	Corn Starch	3.0
50.0	Pecans	10.0

Pecan Candy 2

(g)	Ingredient	(% Total)
366.3	72 Brix Yacon Syrup	73.3
18.8	Butter	3.8
37.5	Evaporated Milk	7.5
18.8	Water	3.8
8.8	Corn Starch	1.8
50.0	Pecans	10.0

Pecan candies were made by first adding butter and 72° Brix yacon syrup to a pot and bringing the mixture to a boil. The corn starch was dispersed in water and added to the mixture at 90°C. In preparing Pecan Candy 1, the evaporated milk was added once the mixture reached 105°C. For the second formula, Pecan Candy 2, the decision was made to wait to add the evaporated milk until the mixture reached 110°C to reduce scorching of the mixture on the bottom of the pot. Once the evaporated milk was added, it was essential to stir the mixture constantly. For both formulas, pecans were added to the mixture once it reached 110°C. As with caramels, the point at which to remove the mixture from the heat source depends on the targeted texture of the end product. In this research, Pecan Candy 1 was removed from heat after the temperature reached 106.9°C (firm ball stage) producing a soft candy. Note that the addition of the pecans at 110°C lowers the temperature of the mixture. Pecan Candy 2 was removed from heat at 124°C (hard crack stage), producing a hard candy.

Hard Candy with Powdered Milk 2

(g)	Ingredient	(% Total)
463.4	72 Brix Yacon Syrup	92.7
36.6	Powdered Milk	7.3

Hard Candy with Powdered Milk 2 was made by bringing the 72° Brix yacon syrup to 90°C, and then mixing in dry powdered milk. This mixture was cooked, stirring constantly, until the hard crack stage was reached (123°C).

Unsuccessful Formulas

The following formulas are considered to have little potential to produce high quality candies. Most were dismissed from further research due to problems with the candies not keeping their form, or becoming sticky or soft on the surface. In cases where other problems were cause for dismissal, an explanation is provided along with the formula. Note that in some cases, precise temperatures for ingredient or heat removal temperatures are not given. This is

due to the fact that these formulas were tested before a digital thermometer was available for precise determination of the syrup temperature.

Hard Candy with Potato Starch 1

(g)	Ingredient	(% Total)
422.5	72 Brix Yacon Syrup	84.5
70.5	Water	14.1
7.0	Potato Starch	1.4

Hard Candy with Potato Starch 2

(g)	Ingredient	(% Total)
419.0	72 Brix Yacon Syrup	83.8
50.0	Water	10.0
30.0	Potato Starch	6.0
1.0	Vanilla	0.2

Both of these hard candy formulas were made by bringing 72° Brix yacon syrup to a boil. The corn starch was dispersed in water and added to the mixture once the soft ball stage was reached. The syrup and corn starch mixture was cooked, stirring occasionally, until the syrup reached the hard crack stage.

These candy formulas were not considered successful due to the texture of the finished product. It is believed that the granule size of the chuno (potato starch) creates a rough, sandy mouth feel.

Hard Candy with Corn Starch 1

(g)	Ingredient	(% Total)
422.5	72 Brix Yacon Syrup	84.5
70.5	Water	14.1
7.0	Corn Starch	1.4

Hard Candy with Corn Starch 2

(g)	Ingredient	(% Total)
419.0	72 Brix Yacon Syrup	83.8
50.0	Water	10.0
30.0	Corn Starch	6.0
1.0	Vanilla	0.2

Hard Candy with Corn Starch 3

(g)	Ingredient	(% Total)
395.1	72 Brix Yacon Syrup	79.0
85.5	Water	17.1
18.4	Corn Starch	3.7
0.9	Vanilla	0.2

These three hard candy formulas were made by heating the 72° Brix yacon syrup to 110°C. The corn starch was dispersed in water and added to the mixture at 110°C. The syrup and corn starch mixture was cooked, stirring occasionally, until the syrup reached the hard crack stage (~119°).

These formulas were deemed unsuccessful due to problems with changes in the form of the candy, softness and stickiness. Better results were achieved when the same proportions of ingredients were used but the starch addition temperature was changed to 90°C.

Hard Candy with Corn Starch 1B

(g)	Ingredient	(% Total)
422.5	72 Brix Yacon Syrup	84.5
70.5	Water	14.1
7.0	Corn Starch	1.4

While the ingredient proportions for this formula are the same as those of Hard Candy with Corn Starch 1, the temperature of starch addition was altered. In the 1B process, the 72° Brix yacon syrup was heated to 90°C. Then, the corn starch was dispersed in water and added to the mixture. The syrup and corn starch mixture was cooked, stirring occasionally, until the syrup reached the hard crack stage (~119°).

While the candies made using the 1B process were better than those made with the Hard Candy with Corn Starch 1 process, there were still problems with changes in the form of the candy, softness and stickiness.

Hard Candy with Powdered Milk 1

(g)	Ingredient	(% Total)
380.0	72 Brix Yacon Syrup	76.0
50.0	Powdered Milk	10.0
50.0	Water	10.0
20.0	Potato Starch	4.0

This formula was made by heating the 72°Brix syrup to the soft ball stage and then adding the potato starch (dispersed in water) and the powdered milk. This mixture was then heated to the hard crack stage. The finished candy from this formula became soft and sticky in a short amount of time, and lost its original shape.

Hard Candy with Powdered Milk 3

(g)	Ingredient	(% Total)
450.0	72 Brix Yacon Syrup	90.0
50.0	Powdered Milk	10.0

This formula was made by heating the 72°Brix syrup to the soft ball stage and then adding the powdered milk. The formula was deemed unsuccessful because it was essentially impossible to incorporate this level of powdered milk into the formula without the occurrence of scorching.

Forming Yacon Candies

Depending on the type of candy being produced, there are several options for molding the hot syrup into different shapes. Below, each small-scale forming process is described and recommendations are given as to which formulations work best with these methods.

- Knife & Cutting Board

  This is the most inexpensive method of forming candy, as it requires no special equipment. First, the hot candy syrup is poured onto a greased surface. An aluminum foil lined tray with a layer of oil or butter works well for this purpose. If the height of the individual candies is of concern, it is important to confine the syrup to a defined space so that it will not spread into a very thin layer.

  Once the candy mass is still hot, but no longer runs like a liquid, it is possible to transfer the aluminum foil containing the candy to a cutting board. The candy can then be cut into squares using a buttered or oiled knife. To do this, cut half way into the candy mass, scoring the surface. This may need to be repeated several times because if the candy has not quite cooled to the ideal temperature, it may flow together again and lose the indented shape made by the knife. Repeating this process however, is better than allowing the candy to cool too much, leaving you with a solid mass that can no longer be formed.

Figure 6: Greasing aluminum foil with butter and a piece of wax paper. Photo by Caitlin Boon.

Figure 7: Pouring hot candy into foil-lined tray. Photo by Caitlin Boon

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er all of the indentations have been made in the candy mass it should be allowed to cool completely. Once cool, the mass may be flipped over and the aluminum foil can be easily removed. The candy can then be broken or cut along the scored lines and packaged. This forming method can work for all candy formulations. It works

Figure 8: Scoring the surface of the solidifying candy with a buttered knife. Photo by Caitlin Boon

especially well with the formulas that contain pecans. While this method can be used with hard candy, it can produce undesirable sharp edges as the candy is in a glassy state.

- Sheet Molds

  The first step in using these molds is to grease the entire mold surface with oil or butter to prevent the candy from sticking. Forming candies using sheet molds must be done very quickly as the hot candy mass cools very quickly as it is poured out of the pot in which it was made. The best way to fill these molds is to use a funnel. Once the candies have cooled, the mold can be turned over to release the candies. Note that this method has not been perfected with yacon candy. A discussion of the problems encountered with this method is included in the Special Concerns section.

- Drop Roller

  To use this machine, the hot candy is poured out of the cooking pot or kettle and allowed to cool slightly on a forming table. When the candy has cooled to the point in which it has some structure and can be picked up and formed into a mass, it is fed through the drop roller. As the candy is cooling on the forming table it should be continuously moved so that one part of the mass will not become rigid before the rest of the mass is cooled to the correct consistency. To work with this hot candy mass, one should use greased, leather gloves and hand-held, greased metal paddles. Feeding the candy mass into the drop roller is best done by two people – one person to feed the candy into the roller, and another to turn the hand crank and ensure that the candies exiting the roller do not fold onto one another. As the candy pieces emerge from the drop roller, a thin layer of candy is between the candy pieces. Once the candy cools completely on a flat surface, this thin layer between the pieces can be broken and sifted away from the formed pieces. This forming method works best with candy formulations heated to the hard crack stage.

Packaging

Figure 9: Candies wrapped in wax paper. Photo by Caitlin Boon

During my research , the candies were individually wrapped in wax paper, placed in metallized film bags and hermetically sealed. Even with the exclusion of humid air, some of the formulations tent to stick to the wax paper. Ideally, these candies should be individually packaged in "pillow packs" made from a material that can be completely sealed from the air. A better packaging method is needed for yacon candies.

Figure 10: Example of "pillow pack" candy packaging. Photo by Caitlin Boon

Section 8: Taste Test Results

In April of 2003, a taste test was conducted with the seven most promising candy formulations. Fifty members of the CIP staff were recruited to test the candies. Some of the most important findings are listed in this section. To see the questionnaires used for this test, please see Appendix A.

Triangle Test

A triangle test was conducted to see if there is a noticeable difference between Hard Candies of different Corn Starch concentrations (Hard Candy 2B with 6% corn starch versus Hard Candy with Corn Starch 4B with 4%), and to see if there is a preference for one candy over the other. Except for corn starch to syrup ratios, the two candies did not differ. Results showed the following:

- 53% of those who tested the candies correctly identified which two were of the same formula.
- Of the 53% who correctly identified the candies from the same formula, 48% preferred Hard Candy with Corn Starch 2 and 52% preferred Hard Candy with Corn Starch 4.

Conclusions: Since preferences were split so evenly, the best way to move forward may be to perform a longer shelf life study to see if one formulation performs better over time. This would help in the selection of a final formulation for this type of hard candy. If Hard Candy with Corn Starch 4 proves to hold up well over time, it would be preferred as it uses less starch.

Candy Ratings

Subjects were asked to rate the flavor and the texture of six of the candy formulations. They were given two lines (one for flavor and one for texture) and asked to rate them on a scale from 1 to 10. The "1" rating was to be given to candies with a very bad flavor or texture, and the "10" rating was to be given to candies with a very good flavor or texture. The average rating for each formulation is given in Tables 2 and 3.

Table 2: Texture Ratings

	Hard Candy with Corn Starch 4	Powdered Milk 2	Caramel with Corn Starch 2	Caramel with Corn Starch 4	Pecan 1	Pecan 2
Average	4.9	3.9	6.8	7.4	8.3	5.1
Standard Deviation	2.6	2.2	1.9	1.8	2.1	2.6

Table 3: Flavor Ratings

	Hard Candy with Corn Starch 4	Powdered Milk 2	Caramel with Corn Starch 2	Caramel with Corn Starch 4	Pecan 1	Pecan 2
Average	6.1	4.3	5.6	6.7	8.3	7.3
Standard Deviation	2.2	2.3	2.5	2.2	1.9	2.4

Conclusions: Based on these results, it is clear that softer textures are preferred. All of the soft caramel/toffee style candies (both caramel samples and the Pecan 1 sample) received higher texture ratings than the hard candy samples. The pecan candies were clearly seen as having the best flavor of all of the candies, indicating that more work should be conducted with incorporating different types of nuts into the candy formulations. The Powdered Milk 2 sample did not receive such rewarding ratings, and actually received the lowest ratings for both flavor and texture, indicating that it may not be a good choice to market.

Willingness to Purchase

Subjects were asked to answer several questions about purchasing yacon candies. First, they were asked whether they would buy each of the different candy types tasted. The results from this question are displayed in Tables 4, 5, and 6. In Tables 5 and 6 the results have been broken down by gender.

Table 4: Number of females willing to buy the candy

	Age Groups (years)				
Candy Formula	**20-29**	**30-39**	**40+**	**Total**	**%**
Hard Candy with Corn Starch 4	11	7	4	22	73
Powdered Milk 2	3	4	0	7	23
Caramel with Corn Starch 2	8	6	4	18	60
Caramel with Corn Starch 4	12	6	5	23	77
Pecan 1	10	8	6	24	80
Pecan 2	8	6	4	18	60
# Responses	15	8	7	30	100

Table 5: Number of males willing to buy the candy

	Age Groups				
Candy Formula	**20-29**	**30-39**	**40+**	**Total**	**%**
Hard Candy with Corn Starch 4	6	3	3	12	60
Powdered Milk 2	0	1	2	3	15
Caramel with Corn Starch 2	3	2	4	9	45
Caramel with Corn Starch 4	6	3	3	12	60
Pecan 1	8	3	4	15	75
Pecan 2	6	4	4	14	70
# Responses	9	7	4	20	100

Table 6: Combined Data for males and females willing to buy the candy

Candy Formula	**Female**	**Male**	**Total**	**%**
Hard Candy with Corn Starch 4	22	12	34	68
Powdered Milk 2	7	3	10	20
Caramel with Corn Starch 2	18	9	27	54
Caramel with Corn Starch 4	23	12	35	70
Pecan 1	24	15	39	78
Pecan 2	18	14	32	64
# Responses	30	20	50	100

Conclusions: The responses show that there is potential for a number of these formulations to be successful in the marketplace. Clearly, the Pecan 2 samples were liked the most as they received the highest texture and flavor ratings as well as having the greatest percentage of people willing to purchase them. Powdered Milk 2 samples were not liked by enough subjects to warrant further testing of formulas using powdered milk.

More work is needed to establish a target market for this product. Other than the Pecan 2 formulation, women were generally more approving of the candies than men. However, more testing with a larger subject group would be valuable to better determine other preferences among different age groups and genders. A test involving children would also be very useful as this age group is a huge consumer of candy products.

Suggested Price and Frequency of Purchase

Subjects were then asked questions about how much they would be willing to pay for the candy and how frequently they would purchase. Responses are shown in Tables 7 and 8. The price levels are given in soles (s/.). At the time of this taste test the exchange rate was 3.45 soles per U.S. dollar.

Table 7: Price subjects willing to pay for a bag containing 50 piece of candy

	Female				Male				Total	
s/.	20-29	30-39	40+	Total	20-29	30-39	40+	Total	Responses	%
2-4.99	2	1	2	**5**	2	1	0	**3**	**8**	**17.8**
5-7.99	6	3	2	**11**	4	5	2	**11**	**22**	**48.9**
8-10.5	6	0	1	**7**	2	0	1	**3**	**10**	**22.2**
10.51-15	1	0	0	**1**	1	0	1	**2**	**3**	**6.67**
15+	0	2	0	**2**	0	0	0	**0**	**2**	**4.44**
Total	15	6	5	**26**	9	6	4	**19**	**45**	**100**

Table 8: Frequency of Purchase

Frequency	%
Daily	20
Weekly	57
Monthly	18
Never	4

Conclusions: This data indicates that the best price for a 50 piece bag (~100g) of yacon candy is between s/. 5-8. The data on frequency of purchase is somewhat difficult to interpret as some responses were for the purchase of individual pieces of candy, and others were for the purchase of a bag of candy. In future tests, this question should be reworded to avoid this problem.

Section 9: Special Concerns

Over the course of this research, several areas have been identified as needing more research. This section is devoted to discussing these concerns and includes recommendations for possible research steps.

- Cold Flow of Candies

  Sometimes in hot, humid conditions, moisture from the atmosphere may be absorbed by candy pieces. This can cause the candy to essentially turn back into syrup. Yacon candies are especially prone to this problem because oligofructans (one of the main sugars in yacon syrup) are very hygroscopic.

Figure 11; Cold flow in yacon hard candy. Photo by Caitlin Boon

There are several ideas as to how to help prevent this problem. First, it is a good idea to cook the candy to the upper end of the desired texture range, with the expectation that over time the candy will become slightly softer.

Table 9: % Change in Weight Once Candy Removed from Hermetically Sealed Packaging

	Hard Candy with Cornstarch 4		Powdered Milk 2		Pecan 1	
Average % Change in Weight	**Wrapped**	**Unwrapped**	**Wrapped**	**Unwrapped**	**Wrapped**	**Unwrapped**
	(%)	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**
After 24 Hours	0.51	0.86	0.42	0.76	0.28	0.54
Standard Deviation	0.036	0.043	0.10	0.025	0.016	0.045
After 6 Days	1.9	3.0	1.6	2.5	1.0	1.7
Standard Deviation	0.11	0.054	0.38	0.084	0.097	0.037

Second, airtight packaging should be used to prevent exposure of the candies to humid conditions. In a preliminary experiment, three types of yacon candies were left out on a counter to determine how quickly moisture is absorbed and the quantity of moisture uptake required for a change in candy texture. Table 9 shows the percent change in weight of the candy samples tested after 24 hours and six days. After 24 hours, the candies were showing slight signs of cold flow such as stickiness and softness on the surface. After six days, some of the candies were showing more severe signs of cold flow and had become very sticky and soft, and had lost their original shape. In both time periods, the wrapped pieces showed less extreme signs of cold flow, even though they were only wrapped in wax paper. Even though this packaging did reduce moisture gain, other packaging options would probably reduce moisture gain even further.

Finally, other ingredients may help to reduce cold flow. As described in previous sections, some starches have been tested in candy formulations and these have been successful in improving the texture of the candies over storage time. More research should be conducted to determine whether other ingredient options exist. One option, Stabilite SD60 Hydrogenated Starch Hydrolysate supplied by SPI Polyols, Inc., was briefly tested just before my time at CIP ended. The Stabilite starch is designed to help reduce cold flow when used at a level of ~15% of the total formulation. This starch produced a candy with better clarity and texture than other starch-containing hard candy formulations tested, but there was insufficient time to determine its ability to reduce cold flow.

- Candy Mold

During this research, a round candy mold was fabricated in an effort to produce ~100 small lozenges quickly. To this point, the mold has not been very successful. The candies tend to get stuck in the molding wells. It is thought that more could be done to smooth out the mold and improve the release of the candies. There are also concerns that the candy may contract too much upon

cooling to be molded in this way. It was noticed during this research that there is substantial shrinkage of the candy volume as the mass cools. More testing should be done to determine the degree of this volume change. In addition, it may be necessary to create and test new mold designs.

- Safety of Yacon Candies

  To date, no studies have been conducted to determine the entire chemical makeup of yacon syrup and evaluate whether there are any toxicological or allergen concerns with this product. It is recommended that a study be conducted to ensure the safety of the syrup and the candies made from this syrup. This would especially be needed if these products were ever sold internationally.

- Hygiene of Candy Makers

  Should this project be deemed successful enough to begin a cottage industry for yacon candy, it will be very important to provide hygiene and sanitation training to candy makers. This will help to ensure the quality and safety of the product.

Appendix A: Taste Test Questionnaires

Thank you for participating!

Please take into account the following items when responding to the questions below:

1. When tasting each sample, please do not let the candy shape or size influence your rating of the candy.
2. Candies from yacon are different from conventional sugar-based candies: they have fewer calories, create fewer dental cavities, are made by local artisans, and they are 100% natural and healthy.

Please drink a small amount of water between tasting each piece of candy.

Participant Information

Age _____ Sex _____

Part 1

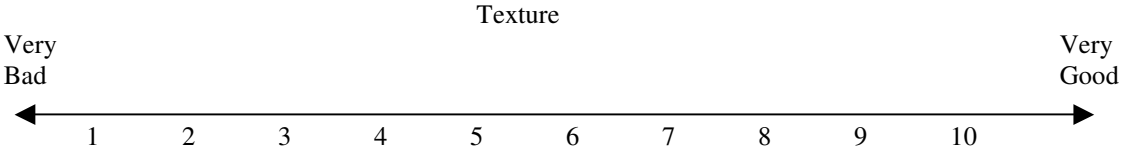
Taste candies numbered 112, 133, and 182. Two of these candies are the same. Which two do you think are of the same batch?

Which candy batch is most pleasing to you?

Part 2

Please taste each candy sample in the order in which they are listed in the table. Evaluate the taste and texture of the candy and write respective sample numbers where you feel the samples fall on the spectrums drawn below.

Sample #	Would you buy this sample?	Comments
112		
114		
199		
146		
139		
105		



How often would you purchase? (everyday, every week, every month, etc.)

If the final shape and appearance of the candy was improved and packaged nicely, how much would you be willing to pay for each piece of candy? For a small bag with 50 pieces of candy?

Would you be more willing to buy samples 133, 182, 112, and 114 if they were advertised as “diet” or “reduced sugar” candies?

Other comments:

Gracias por su participación!

Es importante que tenga en cuenta los siguientes aspectos al momento de responder las preguntas del cuestionario:

1. Nos interesa determinar sólo aquellos aspectos relacionados al sabor del caramelo (la envoltura, la apariencia y otras características diferentes al sabor no deben influenciar en sus respuestas).
2. Los caramelos de yacón son diferentes a los caramelos convencionales: tienen menos calorías, generan menos caries a los dientes, son hechos artesanalmente, son 100% naturales y saludables

Por favor, beba un sorbo de agua después de probar cada caramelo.

Información de Participante

Edad _____ Sexo _____

Parte 1

Pruebe los caramelos designados 112, 133, y 182. Dos de estos caramelos son iguales. Identifique los caramelos que Ud. cree son iguales.

¿Cuál de los caramelos le gusta más?

Parte 2

Pruebe cada muestra según el orden de la tabla y escriba unos cometarios sobre el sabor y/o textura. Califique el sabor y textura de cada muestra escribiendo sus respectivos códigos en las siguientes rectas de evaluación.

Muestra #	¿Compraría esta muestra?	Comentarios
112		
114		
199		
146		
139		
105		

¿Con qué frecuencia compraría Ud. este caramelo? (cada día, cada semana, cada mes, etc.)

Si el producto tuviera una mejor presentación final y una mejor envoltura, cuánto estaría dispuesto a pagar Ud. Por:
un caramelo:
una bolsa de 50 caramelos:

¿Estaría Ud. más dispuesto a comprar los caramelos 112, 114, 133, y 182 si fueran promocionados como caramelos "diet" o "bajo en azúcar"?
Otro comentaríos:

Appendix B: Candy Links

Trade Associations

National Confectioners Association (United States)
8320 Old Courthouse Road
Suite 300
Vienna, VA 22182
Phone: (703) 790-5750
E-mail: info@candyusa.org
Website: http://www.candyusa.org -- Links to ingredient and equipment companies.

Contacts

Caitlin Boon
12801 Mayes Rd
Huntersville, NC 28078
Cell Phone: (704) 453-1080
Home Phone: (704) 892-3326
E-mail: caitlin_boon@yahoo.com
*CIP Volunteer from February to May 2003 and author of this report

John Holland
J Holland Corporation
4916 Londonderry Drive
Tampa, FL 33647
Phone: (813) 979-1929
Worldwide Cell Phone: (813) 598-6184
E-mail: john@jhollandcorp.com
Website: www.jhollandcorp.com
*Supplier of drop rollers and other small scale candy equipment

SPI Polyols, Inc.
321 Cherry Lane
New Castle, DE 19720-2780
E-mail: spiperu@attglobal.net
Website: www.spipolyols.com
*Supplier of Stabilite SD60 Hydrogenated Starch Hydrolysate

Appendix C: References

McGee, Harold. On Food and Cooking: The Science and Lore of the Kitchen. New York: Fireside, 1984.

Photos:

Boon, Caitlin. International Potato Center. Lima, Peru.

Holland, John. J Holland Corporation. Tampa, FL, USA.