Substitution of Kudzu Starch for Cornstarch Results in Dairy-Based Vanilla Pudding with Similar Texture and Consumer Acceptability

Carissa D. Ingram

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Substitution of Kudzu Starch for Cornstarch Results in Dairy-Based Vanilla Pudding with Similar Texture and Consumer Acceptability

An Honors Thesis Proposal submitted in partial fulfillment of the requirements for Honors in the Department of Health Sciences and Kinesiology.

By
Carissa Ingram

Under the mentorship of Dr. Joelle Romanchik-Cerpovicz

ABSTRACT
Kudzu, also known as kuzu, is a rapidly growing, vine invasive in the Southeastern United States following introduction for soil erosion control in the late 19th century. Native to Southeastern Asia, its roots are rich in starch which has been used in traditional Eastern cuisine as a sauce thickener. Use of kudzu starch in Western cuisine is limited. This study compared the consistency, percent sag, and consumer acceptability of whole milk vanilla pudding prepared with kudzu starch to vanilla pudding prepared with cornstarch, a more commonly used thickening agent in the United States (control). The consistency (Bostwick Consistometer; 50°C) and percent sag (4°C; 24h) of the puddings did not differ. In addition, fifty-one consumers evaluated appearance, smell, creaminess, flavor, aftertaste, and overall acceptability of the puddings using a hedonic scale (9=extremely like, 5=neutral, 1=extremely dislike). Willingness to purchase was also evaluated (9=definitely yes, 5=neutral, 1=definitely no). Overall acceptability of whole milk kudzu starch-thickened vanilla pudding was positive (7.0+/−1.3) and did not significantly differ from corn starch-thickened vanilla pudding (6.2+/−1.8). Appearance, smell, creaminess, flavor, and aftertaste of both puddings were also liked (means+/−SD>5.0) and did not significantly differ. Finally, consumers were similarly willing to purchase (means+/−SD>5.0) both puddings. This work shows that kudzu starch is acceptable as a cornstarch substitute in dairy-based vanilla pudding and may be recommended by registered dietitians as a value-added alternative to corn starch in pudding preparation. Future studies will determine if kudzu starch is similarly acceptable when the fat content of puddings is varied.

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Dr. Joelle Romanchik-Cerpovicz

Honors Director: __________________________

Dr. Steven Engel

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Georgia Southern University
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Abbreviations

ANOVA- analysis of variance

cm- centimeters

g- gram

HDL- high-density lipoprotein

IAB- Interdisciplinary Academic Building

IRB- Institutional Review Board

LDL- low-density lipoprotein

ml- milliliters

SD- Standard Deviation

TCM- Traditional Chinese Medicine
Chapter One: Introduction

1.1 Food Thickeners

1.1.1 Types and Composition

Food thickening agents are food-based substances that can enhance the textural properties of food while not substantially altering product flavor and structure (Wong et al., 2020). In addition, food thickeners may increase the nutritional value in a product adding carbohydrate, including dietary fiber, or protein (Wang et al., 2012).

There are a wide variety of food thickeners, including but not limited to, xanthan gum, pectin, whey protein, and starch. Xanthan gum is a hetero-exopolysaccaride that originates from the bacterium Xanthomonas campestris (Ozdal and Kurbanoglu, 2018). Its properties include thickening, emulsification, stability, pseudoplasticity, and temperature resistance (Apaydin et al., 2019). Pectin is a polysaccharide that is derived from the plant cells or fruit (Wang et al., 2012). Pectin is often used for stability in low-pH foods, as well as gelling and thickening (Wang et al., 2020). Whey protein is a byproduct of the coagulation or precipitation of casein during cheese manufacturing (Wherry et al., 2019). Whey protein is used in food for its gelling and emulsifying capabilities as well as to increase protein content of the product (Wherry et al., 2019). Starch is a polysaccharide that is composed of linear amylose chains and branched amylopectin chains (Krashnow et al., 2011). Common native starches are derived from corn, wheat, tapioca, rice, and potato (Arocas et al., 2009) and have stabilizing, gelling, and thickening properties (Whistler et al., 2009).

1.1.2 Culinary Uses
Xanthan gum is used as a texturizing agent due to its ability to bind large volumes of water (Apaydin et al., 2019). One of the most widespread gums in food production, it is used extensively in dairy products and dessert gels (Apaydin et al., 2019). Xanthan gum has also been used for its thickening and stabilizing capabilities in processed meats, chicken or fish, creams, synthetic juices, salad dressing, syrups and coverings for ice creams and desserts (Apaydin et al., 2019). Because of its excellent thickening ability, xanthan gum is often used as a thickener in the beverages of dysphagia patients where it helps elicit an optimal swallowing response (Kim and Yoo, 2018).

Pectin and polymerized whey protein have been used as thickeners in food products such as to increase the consistency of yogurt. Wang et al. (2012) used pectin and whey protein as gelling agents in a probiotic goat milk-based yogurt. The yogurt was evaluated for its viscosity as well as chemical makeup and changes in pH during storage at 4 degrees Celsius after preparation (Wang et al., 2012). The results showed no significant differences in terms of viscosity, but microstructure analysis determined a relatively more comprehensive network of casein micelles was formed thus resulting in improved consistency and water-holding capacity of the goats’ milk yogurt (Wang et al., 2012). The results of this work suggest that pectin and whey protein may be useful in improving the textural quality of fermented dairy products (Wang et al., 2012).

Yogurts have also been thickened successfully using resistant cassava starch (Mwizerwa et al., 2017). Because resistant starch is known to provide health benefits such as increased fiber intake to consumers, it may be desirable to increase the resistant starch content in common foods (Mwizerwa et al., 2017). In this study, the physicochemical and sensory attributes of cassava resistant starch in yogurt were
determined. Cassava starch was added into yogurt in the proportions of 0, 0.1%, 0.5% and 1% with corn starch (0.6%) used as the control (Mwizerwa et al., 2017). Monitored for 21 days (4 degrees Celsius), there was a significant correlation (p≤0.05) between resistant starch concentration and the physicochemical properties of yogurt in that the addition of cassava starch significantly increased (p≤0.05) the total solids content of yogurt (Mwizerwa et al., 2017). However, the addition of the starch maintained similar acceptable sensory properties to yogurt without the addition of the starch suggesting that cassava starch is an acceptable food thickener for yogurts (Mwizerwa et al., 2017).

1.2 Kudzu

1.2.1 Origins and Growth

Kudzu is a tuberous, climbing, semi-woody and perennial vine with hairy rusty-brown stems (Wong et al., 2011). Kudzu is in the Fabaceae family and it comes from the Pueraria genus. The most common form of kudzu is Pueraria montana var lobata which is one of the first plants to be introduced in Traditional Chinese Medicine (Abascal and Yarnell 2007). In addition, there are many species and variations of the plant which can be differentiated by their forms. For example, medicinal kudzu root is called gegen in Chinese and Puerariae lobatae, edible kudzu is called Pueraria thomsonii Benth, and wild kudzu is P. lobata Ohwi (Wong et al., 2011). Other names used to refer to kudzu in general include kuzu, kudsu, kudzu vine, wayaka, nepalem, and Japanese arrowroot (Wong et al., 2011).

Kudzu originates from Japan and Southeast Asia (Abascal and Yarnell 2007). In 1876, kudzu was first introduced to the United States from Japan to control soil erosion and provide food for cattle (Abascal and Yarnell 2007). During the Great Depression,
kudzu was utilized by the US government for soil stabilization and became known as “the miracle vine” for restoring the quality of poor soil (Abascal and Yarnell 2007). In the US, the growth of kudzu is most prominent in the Southeastern states spanning from Louisiana to Georgia because of the ability of its tuberous roots to survive the winter climate of these regions (Sage et al., 2009).

In addition, kudzu is a very prolific plant that can grow up to a foot a day with a vine diameter of eighteen to forty-five centimeters (Wong et al., 2011). Additionally, in one growing season, a kudzu plant’s growth can increase thirty meters in length (Al-Hamdani et al., 2014). Because of its invasiveness, kudzu accounts for over $500 million annually in environmental damage and expenditures for control in the US (Sage et al., 2009). Although this invasive plant is an economic burden, at this time, its tuberous roots are edible (Chen et al., 2017).

1.2.2 Types and Composition

Kudzu root is composed of a significant amount of starch ranging from 14 to 35 percent of its dry weight (Zhao et al., 2014). Starch consists of two glycosidic macromolecules, amylose and amylopectin of which kudzu starch is reported to contain approximately 20.8–22.9% amylose and 20.5% amylopectin (Zeng et al., 2019). Amylose possesses strong gelling properties and amylopectin is water soluble and produces a stable solution with a very high viscosity (Xie et al., 2017) suggesting that kudzu starch may be used as a food thickener and gelling agent.

Kudzu root also contains two major isoflavones, puerarin, and daidzein, which have been considered bioactive (Zhao et al., 2014). Other components of kudzu include acid-insoluble polysaccharides, acid-soluble polysaccharides, reducing sugar, protein,
free amino acids, and lipids (Zhao et al., 2014). Among the acid-insoluble polysaccharides, fiber is the main constituent, and among the acid-soluble polysaccharides, starch is the most prominent (Zhao et al., 2014).

1.2.3 Food Production and Preparation

Kudzu leaves and the root can both be used in food production (Wong et al., 2011). Kudzu leaves are available for foods that are consumed as a tea, salad, juice, and syrup (Son et al., 2019). Kudzu leaves are high in isoflavonoids. Genistin and daidzein are the major components found in kudzu leaves (Son et al., 2019). Dried kudzu root, known as gegen, is the most used portion of the plant (Wong et al., 2011). Starch is extracted from kudzu root and can be purchased as a powdered extract to thicken foods by increasing the viscosity/firmness (Wong et al., 2011).

While not used in commercial food production at this time, the ability of kudzu starch to thicken and improve the nutritional quality of stirred yogurt was recently examined (Imamoglu 2015). Yogurt is a common dairy product that in recent years, has been consumed not only for its nutritional value, but also for the thickness it imparts to mouthfeel. Corn starch has played a key role in yogurt manufacturing as it increases viscosity, improves mouthfeel, reduces syneresis and makes the overall appearance of the yogurt better without substantially changing the taste of the product (Wong et al., 2020). When kudzu starch was added to yogurt, the thickness of yogurt was increased and desirable sensory properties were maintained (Wong et al., 2020).

Because of its abundance in China and the US, kudzu has the potential to be a cost-effective food that is nutrient dense (Chen et al., 2017). Because of its low cost and high starch content, the Chinese have added it as an additional ingredient to ice cream,
noodles, and jelly (Chen et al., 2017) (Abascal and Yarnell, 2007). In southern China, kudzu has been used locally as an additional ingredient in sausage noodles, pork-bone kudzu-soup, and braised pettitos with kudzu (Al-Hamdani et al., 2014) (Chen et al., 2017).

1.2.4 Disease Prevention and Nutrition

Kudzu root contains antioxidants (Al-Hamdani et al., 2014). Cooking by boiling, frying, and/or steaming methods, results in increased bioavailability of phytochemical antioxidants in kudzu (Chen et al., 2017). Specifically, boiling and steaming increases isoflavonoid bioavailability while frying greatly increases the phytochemical capacities of kudzu (Chen et al., 2017).

In Ancient China, kudzu root was utilized in early Traditional Chinese Medicine (TCM) (Chen et al., 2017). Traditional Chinese Medicine is a medicinal system based on acupuncture, acupressure, Chinese herbs, cupping, and diet. TCM pertains to health practices and approaches and beliefs involving plants and herbs based on ancient and modern pharmaceutical science (Shahrajabian et al., 2019). One of the earliest medicinal herbs used in TCM, kudzu is considered to relieve symptoms of neck stiffness, fever, diarrhea, and help increase the production of body fluids (Chen et al., 2017).

Kudzu root has been used recently to treat chronic drinking problems and intoxication (Pentar et al., 2015). In a clinical study, self-claimed heavy drinkers were treated with placebo or two five hundred milligram capsules of kudzu extract three times a day for seven days (Pentar et al., 2015). The results of the study showed that after treatment, placebo-treated individuals opened more beer cans than kudzu-treated individuals (Pentar et al., 2015).
Research has also indicated that kudzu root may decrease the likelihood of obtaining metabolic syndrome (Peng et al., 2009). Peng et al. (2009) reported that stroke-prone female rats were monitored for 2 months on a polyphenol-free diet with or without the addition of kudzu extract (Peng et al., 2009). After two months, the results showed that rats fed kudzu extract-supplemented diets had significantly lower arterial pressure, blood glucose levels, plasma cholesterol, and fasting plasma insulin than control rats (Peng et al., 2009).

Kudzu root also contains phyto-estrogenic compounds and may have the ability to prevent osteoporosis (Ok et al., 2015). This is important as estrogen levels naturally decrease in women as a result of menopause (Ok et al., 2015).

Kudzu root may also reduce glucose levels and affect reproduction and cancer development. Specifically, rats treated with kudzu root had significant reduction in blood sugar and increased the number and motility in sperm cells in diabetic rats (Bagheri et al., 2016). Kudzu appears to have had properties that reduced blood sugar, improved testicular damage, and provided therapeutic relief to people with diabetes (Bagheri et al., 2016). In addition, kudzu root may have the potential to prevent prostate cell change, an initial step in prostate cancer development (Masrudin and Mohamad 2015). Rats treated with Pueraria mirifica extract significantly inhibited the growth of benign prostatic hyperplasia (Masrudin and Mohamad 2015). The analysis showed a significant improvement in the prostate cells of testosterone-induced rats (Masrudin and Mohamad 2015).

Kudzu flowers from the varieties, *P. lobata* and *P. thomsonii* (Chen et al., 2017), contain high concentrations of isoflavones and saposins (Chen et al., 2017). These
flowers have been utilized to treat alcohol intoxication, alcohol abuse, and dysentery (Chen et al., 2017). In addition, they also contain potent antioxidants which are shown to reduce the major risks of diseases such as cancer and cardiovascular disease. The presence of phenolic compounds in kudzu flowers are the major source of antioxidants in the plant (Al-Hamdani et al., 2014). (Chen et al., 2012). Consumption of the flowers may be beneficial as foods that have high antioxidant levels eliminate free radicals that can be caused by poor diet habits or other environmental factors (Al-Hamdani et al., 2014).

As the largest component of kudzu, puerarin is a constituent that may provide an array of health benefits including increased cardiovascular health, lowered glucose levels in diabetic patients, and neuron protection against apoptosis (Abascal and Yarnell 2007). Kudzu may also possess anti-inflammatory effects. Anti-inflammatory properties may be related to kudzu root's content of puerarin and daidzein (Abascal and Yarnell 2007).

Specifically, puerarin in kudzu reduces swelling and inflammation which can be useful in treating osteoarthritis (Abascal and Yarnell 2007). Obtained by injection or consumed orally by capsule or tablet, the injection form of puerarin is currently utilized for treatment of coronary heart disease, angina pectoris, diabetes, and cerebrovascular disease (Abascal and Yarnell 2007). Puerarin can also often used in combination with other orthodox medicines to treat stroke and heart conditions (Abascal and Yarnell 2007). For oral consumption, capsule form is preferred because tablets are sometimes not very soluble in water (Abascal and Yarnell 2007).

Daidzein is another common isoflavonoid that is produced in kudzu root (Das et al., 2018). It is classified as a phytoestrogen due to its functional and structural similarities to endogenous estrogen (Das et al., 2018). In kudzu roots, daidzein can be
found as a form of glycoside that is biologically inactive and unmodified during various food preparations (Das et al., 2018). The presence of daidzein in its active aglycone form is also found in kudzu roots (Das et al., 2018). Supplementation of daidzein has been shown to have profound effect on the improvement of insulin resistance, obesity associated complications, inflammation, alteration of plasma lipid profile, and dyslipidemia, which may be related to its osteogenic, antiestrogenic, and cholesterol reducing effects (Abascal and Yarnell 2007). In addition, human research indicates that *Pueraria mirifica* increases HDL levels and decreases LDL levels (Ulbricht et al., 2015).

**1.3 Goals of this Project**

Despite its rich starch content and potential associations with disease prevention, no one to date has systematically examined the ability of kudzu starch to modify the texture of dairy-based dessert pudding. Therefore, the principle goal of this project is to determine the physical and sensory properties of vanilla pudding prepared with kudzu starch and to compare these properties to a similar dairy-based vanilla dessert pudding prepared with cornstarch. It is hypothesized that the consistency of pudding prepared with kudzu starch will be similar to pudding prepared with cornstarch and that consumers will similarly like both products.

**Aim 1**

To determine the consistency of vanilla pudding prepared with kudzu starch.

**Aim 2**

To compare the consistency of vanilla pudding prepared with kudzu starch to similar vanilla pudding prepared with cornstarch.
Aim 3

To determine consumer acceptability of vanilla pudding prepared with kudzu starch and vanilla pudding prepared with cornstarch.

Aim 4

To compare the consumer acceptability of vanilla pudding prepared with kudzu starch to similar vanilla pudding prepared with cornstarch.
Chapter Two: Materials and Methods

2.1 Pudding Preparation

2.1.1 Materials

*Ingredients:*

- 19.2 g Starch (Eden Organic Kuzu/Kudzu Root Starch or Argo Cornstarch)
- 65.0 g Granulated Sugar (Great Value)
- 486.6 g Whole Milk (Food World Brand)
- 4.2 g Vanilla Extract (McCormick’s)
- 5.0 g Butter (Great Value)

*Other:*

- Balance
- Double Boiler
- 3-quart saucepan
- Spoon
- Whisk
- Ladle
- Plate
- Candy Thermometer
- Custard Cups
- Testing Cups
- Bostwick Consistometer
- Saran Wrap
- Disposable Plastic Spoons
Distilled Water
Disposable Plastic Cups
Napkins
Trays
Consent Letters
Questionnaires
Surveys

2.1.2 Methods

Prior to cooking, all ingredients were weighed out using a scientific balance. The kudzu root starch, in chunk form, was ground into a powder using a mortar and pestle prior to being weighed out. Two sets of ingredients were weighed out- one set with all the ingredients weighed for the pudding using kudzu starch, and one set for the pudding using corn starch (control).

In a double boiler, above a 3-quart saucepan, either kudzu starch or corn starch and sugar were mixed until evenly distributed with the back of a spoon. Milk was gradually added to the starch and sugar mixtures, stirring with the back of a spoon for 1 minute for dispersion. A candy thermometer was then added to the double boiler. The mixture was cooked on medium gas heat with continuous stirring with a wire whisk until the pudding mixture reached 90 degrees Celsius. The pudding continued to cook with continuous stirring at 90 degrees Celsius for 20 minutes. Adjustments in gas level were made during cooking to maintain temperature. After cooking, the pudding was removed from the heat and the vanilla and butter were gently mixed into the pudding with the wire
whisk for one minute until evenly dispersed. The pudding was then either cooled to 50 degrees Celsius and evaluated for consistency, poured into custard cups in \( \frac{1}{2} \) cup measures for percent sag objective assessment, or put in 2 tablespoon measures in individual serving cups for sensory evaluation, covered with plastic wrap, and chilled for 24 hours at 4 degrees Celsius.

2.2 Sensory Evaluation

2.2.1 Subjects

Fifty (51) consumers consisting of faculty, students, and staff at Georgia Southern University were asked to evaluate both vanilla pudding containing kudzu starch and vanilla pudding containing cornstarch. Volunteers were given the right to refuse participation in the study and were able to stop participation at any time during the study without penalty. Any person with a food allergy of any of the ingredients used in the evaluation were not allowed to participate in the study.

Puddings were subjectively evaluated by individual panelists in the Sensory Evaluation Room within the Interdisciplinary Academy Building at Georgia Southern University. In a connecting Experimental Food Science Laboratory, samples of pudding and other supplies were prepared for analysis. An evaluation tray for each participant, contained a pudding testing cup, a napkin, a disposable plastic spoon, and a disposable plastic cup of distilled water. Each pudding cup was coded to allow the researcher to differentiate if it contained pudding prepared with kudzu starch or with cornstarch.

Entering the Sensory Evaluation Room, each participant sat at one of seven testing booths and was instructed not to converse with any other participant. Each
participant was then given a packet in which they recorded their responses. The packet included a consent form, questionnaire of consumption patterns, and surveys for each of the two pudding being sampled. Each participant completed the consent form, indicating any food allergies. If an allergy to one of the ingredients in the puddings was reported, then the participant was excluded from further analysis of the products. Each participant was also asked to complete the questionnaire of consumption patterns. After completing the forms, the participants were instructed to press the button next to their booth which would indicate to researchers that they were ready to evaluate a pudding sample.

A sample of pudding was pushed through into the Sensory Evaluation Room by way of a bread box door whereby neither the researcher nor the participant could see each other. After a pudding sample, the participants were instructed to cleanse their palates with distilled water and to slide their test tray through the bread box door and press the light again to receive the next pudding sample.

2.2.2 Instrumentation/Presentation

Utilizing a hedonic scale where 1= extremely dislike, 5= neither like or dislike, and 9= extremely like, participants evaluated the appearance, smell, creaminess, flavor, aftertaste, and overall acceptability of each pudding. In addition, willingness to purchase either pudding prepared with kudzu starch or corn starch was evaluated by the scale 1= definitely no, 5= maybe, and 9= definitely yes. The survey instrument that was used in the study is presented in Appendix A.

2.2.3 Approval
Institutional review board (IRB) approval was obtained for research using human subjects. Specifically, B-6 Food Tasting exempt status approval was obtained (See Appendix B).

2.3 Objective Analysis

2.3.1 Consistency

The consistency of each the pudding was evaluated using a Bostwick Consistometer. Freshly prepared pudding was cooled at room temperature (25°C) until the product temperature reached 50°C. The reservoir of the consistometer was filled with 95 ml of pudding sample and the gate was released to allow the product to flow. After 30 seconds, five measurements (in cm) were recorded to indicate how far the pudding flowed (one in the center of the consistometer, one each on the two outer edges of the instrument, and one each on the two areas midway between the outer edges and the center of the consistometer). All five values were averaged and constituted for consistency measurement for a particular pudding sample. Three fresh samples of each type of pudding were assessed.

2.3.2 Percent Sag

Each pudding’s structural strength was also evaluated by percent sag (McWilliams, 2017). Freshly prepared puddings (118.3mL) in individual Pyrex custard cups were wrapped in plastic and allowed to congeal for 24 hours at 4°C. The percent sag of each 118.3 mL pudding sample was then determined as the depth of a congealed pudding (mm) decreased after unmolding from the Pyrex custard cup compared to its
original depth (mm) in the custard cup multiplied by 100 (McWilliams, 2017). Three samples of each type of pudding were assessed.

2.4 Statistical Analysis

Consistency and percent sag measurements (mean +/- standard deviation of n=3 for each) were analyzed using repeated measures analysis of variance (ANOVA) with post-hoc testing by Tukey-Kramer multiple comparisons using InStat Instant BioStatistics (version 3.0 for Windows, 1998-1999, Graph Pad Software, Inc, San Diego, CA). Significance was set at p< 0.05.

Sensory evaluation scores (mean +/- standard deviation of N=50) were analyzed using an unpaired T-test with analysis conducted by InStat Instant BioStatistics (version 3.0 for Windows, 1998-1999, Graph Pad Software, Inc, San Diego, CA). Significance was set at p<0.05.
Chapter Three

Results

3.1 Texture of Puddings

The consistency (cm) of the whole milk pudding prepared with cornstarch had a range of 6.93 cm to 8.45 cm while that of the whole milk pudding prepared with kudzu ranged from 5.70 cm to 7.12 cm (Table 1). There was a trend which showed whole milk pudding prepared with cornstarch (control) may be thicker in comparison to the whole milk pudding prepared with kudzu. However, the difference in the mean values was not significant.

The sag (%) of the whole milk pudding prepared with cornstarch had a range of 14.83% to 20.37% while the percent sag of the whole milk pudding prepared with kudzu ranged from 19.49% to 22.71% (Table 1). While the mean percent sag for the kudzu thickened pudding, 21.1 %, appeared larger than the mean percent sag of the cornstarch thickened pudding, 17.6 %, the values were also not significantly different.

3.2 Demographics of the Consumer

The demographics of the consumer panel who evaluated the puddings are displayed in Table 2. In total, there were fifty-one participants. There were 41 females (80.4%) and 10 males (19.6%). Their mean age was 22.3 years.

Table 2 also shows the personal consumption patterns of the panelists. Of the fifty-one participants, forty-eight (94.2%) of them noted consuming desserts at least monthly.
Table 1. Texture of Puddings

<table>
<thead>
<tr>
<th>Objective Evaluation</th>
<th>Whole Milk Cornstarch (control)</th>
<th>Whole Milk Kudzu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistency (cm)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.69 +/-0.76</td>
<td>6.41 +/-0.71</td>
</tr>
<tr>
<td>Sag (%)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.6 +/-2.77</td>
<td>21.1 +/-1.61</td>
</tr>
</tbody>
</table>

<sup>a</sup> n=3, No significance

<sup>b</sup> n=3, No significance
Table 2. Demographics of the Consumer (N=51)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>22.3 +/- 6.6 years</td>
</tr>
<tr>
<td>Sex</td>
<td>Female: 80.4% (N=41)</td>
</tr>
<tr>
<td></td>
<td>Male: 19.6% (N=10)</td>
</tr>
<tr>
<td>Consumption Patterns</td>
<td>Desserts- At least monthly: 94.2% (N=48)</td>
</tr>
</tbody>
</table>
3.3 Consumer Acceptability

As shown in Table 3, the puddings were liked (means > 5) by the consumers for all characteristics. In addition, overall acceptability mean ratings ranged from 6.24 to 6.98 and did not significantly differ.

While it did not reach significance, it was noted that the rating for the flavor of the whole milk pudding prepared with kudzu was slightly higher than the pudding prepared with cornstarch. Appearance, smell, creaminess, and aftertaste were also well liked by the consumers (means > 5) and did not differ significantly between the puddings. Consumers were also similarly willing to purchase both puddings. The consumers’ willingness to purchase either pudding was also positive (means >5) and did not differ between the puddings.

3.4 Compositional Analysis

As shown in Table 4, the whole milk cornstarch pudding and the whole milk kudzu pudding were comparable in Calorie and macronutrient composition. The pudding prepared with cornstarch contained 160.0 Calories while the pudding prepared with kudzu contains 171.1 Calories. In terms of the macronutrients, the results were also very similar. Both puddings contained Calories which were 64% carbohydrates, 27% fat, and 9% protein.
### Table 3. Consumer Sensory Data (N=51)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Whole Milk Cornstarch (control)</th>
<th>Whole Milk Kudzu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appearance</strong></td>
<td>6.71 +/-1.80</td>
<td>5.92 +/-1.64</td>
</tr>
<tr>
<td><strong>Smell</strong></td>
<td>5.71 +/-1.64</td>
<td>6.47 +/-1.63</td>
</tr>
<tr>
<td><strong>Creaminess</strong></td>
<td>6.43 +/-2.34</td>
<td>6.07 +/-1.70</td>
</tr>
<tr>
<td><strong>Flavor</strong></td>
<td>6.29 +/-2.11</td>
<td>7.26 +/-1.56</td>
</tr>
<tr>
<td><strong>Aftertaste</strong></td>
<td>5.98 +/-2.02</td>
<td>6.35 +/-1.91</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>6.24 +/-1.76</td>
<td>6.98 +/-1.32</td>
</tr>
<tr>
<td><strong>Willingness to Purchase</strong></td>
<td>5.67 +/- 2.25</td>
<td>6.11 +/- 2.01</td>
</tr>
</tbody>
</table>

---

**Hedonic Scale**

- 1. Extremely Dislike
- 5. Neither Like nor Dislike
- 9. Extremely Like

**Hedonic Scale**

- 1. Definitely No
- 5. Neutral
- 9. Definitely yes
Table 4. Compositional Analysis of Puddings

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Whole Milk Cornstarch (control)</th>
<th>Whole Milk Kudzu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (k-cal)</td>
<td>160.0</td>
<td>171.1</td>
</tr>
<tr>
<td>Carbohydrate (g; % k-cal)</td>
<td>25.5 g; 64%</td>
<td>27.3 g; 64%</td>
</tr>
<tr>
<td>Total Fat (g; % k-cal)</td>
<td>4.8 g; 27%</td>
<td>5.1 g; 27%</td>
</tr>
<tr>
<td>Protein (g; % k-cal)</td>
<td>3.7 g; 9%</td>
<td>3.9 g; 9%</td>
</tr>
</tbody>
</table>

* Macronutrient content per 100 g prepared product

Source: USDA Food Data Central; http://fdc.nal.usda.gov;

Chapter 4

Summary and Discussion

The main goal of this study was to determine the physical properties and sensory acceptability of vanilla pudding prepared with kudzu starch and to compare these properties to a similar dairy-based vanilla dessert pudding prepared with cornstarch. At the start of the research, it was hypothesized that the consistency of pudding prepared with kudzu starch would be similar to pudding prepared with cornstarch and that consumers would similarly like both products. The results of the research support this hypothesis as the consistency of the whole milk cornstarch pudding objectively did not significantly differ from the whole milk kudzu pudding. There were also no significant differences subjectively in the overall acceptability, individual sensory characteristics, or willingness to purchase both puddings.

The first aim of this research was to determine the consistency of vanilla pudding with kudzu starch. This was determined by preparing fresh pudding, cooling it to 50 degrees Celsius as similarly done in a study by Mohammed Alamri et. al. (2014) and placing a sample into the reservoir of the Bostwick consistometer to obtain measurements. The consistency of the kudzu pudding was acceptable. The kudzu starch effectively thickened the pudding.

Aim 2 of this research was to compare the consistency of the two puddings. The consistency of the whole milk pudding prepared with cornstarch was similar to that of the pudding prepared with kudzu. The consistency of the pudding prepared with cornstarch appeared to slightly be thicker and have a slightly lower percent sag than that of the kudzu prepared pudding. This data suggests that the amount of amylose present in kudzu
root may be slightly lower than that of cornstarch. Kudzu contains about 21% amylose while cornstarch typically ranges from 24-28% amylose (McWilliams, 2016). Amylose provides the gelling property to starches, so starches higher in amylose content have a stronger ability to gel in comparison to starches with a lower amylose content. Root starches also tend to form weaker gels than cereal starches because they are lower in amylose content (McWilliams, 2016). Cereal starches also form better gels which explains why the corn starch thickened pudding had a thicker consistency. However, these values did not reach significance. It is likely that the values did not reach significance as the percent ranges of amylose between the starches are not drastically different. However, although not significant, the percent sags may have reached significance if more than three samples of each product were analyzed.

The third and fourth aim were to determine and compare the consumer acceptability of the vanilla pudding prepared with kudzu starch to the similar vanilla pudding prepared with cornstarch. All of the consumer acceptability ratings of the characteristics of the puddings were similar. The mean for each characteristic were all above 5, indicating they were all well-liked by the consumers. While it did not reach significance, the kudzu prepared pudding had a slightly higher mean value for flavor acceptability. This suggests that kudzu root may have the ability to enhance the flavor of foods; however, with limited research available on the composition of kudzu, more research would need to be done to draw this conclusion. The whole milk cornstarch prepared pudding also received a slightly higher, but not significantly different, acceptability rating than the kudzu prepared pudding for appearance. This was not expected as both puddings were prepared the using the same methods and both had a
similar eggshell white look. Once again, this difference did not reach significance. Consumers were just as likely to purchase pudding prepared with kudzu as pudding prepared with cornstarch.

One limitation in this study was the sample size of the consumers (N=51). If the panel was composed of at least 30 to 50 more consumers, it may have provided stronger results. The consumer sensory evaluation could not be expanded due to research restrictions with the COVID-19 virus around the time the study was completed. In addition, it would have been valuable to have had a consumer panel that enjoyed pudding more. Some of the panelists completed the survey without having a strong liking but rather a neutral opinion about pudding, which may have impacted their decision making on the consumer acceptability rankings.

In the future, this study could be expanded to analyze the effects of varying milk fat content of puddings on consistency, percent sag, and consumer acceptability of vanilla pudding prepared with kudzu in comparison to vanilla pudding prepared with cornstarch. Whole milk is typically used as the standard in many recipes. From a nutrition standpoint, it would be interesting to see if using milk with a lower fat content could provide a similarly acceptable pudding that may be lower in Calories. If continuing this study, it would be beneficial to expand to a larger sample size. In addition, it would be interesting to test how kudzu starch behaves in terms of its ability to modify the texture of other food products. While starches possess the ability to thicken food products, they can also improve the texture and serve as stabilizing agents in baked foods. It would be beneficial to examine the effect of kudzu starch on texture of baked products as it could provide a
similarly acceptable alternative to cornstarch while also possibly providing additional nutritional benefits.

In conclusion, this study is relevant for future use by dietitians and other nutrition professionals. This study supports the theory that kudzu starch is acceptable as a cornstarch substitute in dairy-based vanilla pudding and can be used by dietetics professionals as a value-added alternative to cornstarch in pudding preparations. Since kudzu root is rich in antioxidants which may reduce the risk of developing chronic diseases, it may also be beneficial to conduct further biomedical research to examine the role of kudzu in disease prevention and improving nutritional status (Al-Hamdani et al., 2014, Peng et al., 2009). Since kudzu root may provide health benefits and be useful in food preparations, it is possible that it will become more widely used in the future, especially in Western food preparation. Overall, kudzu starch is a cornstarch alternative which may help nutrition and food science professionals encourage consumers to improve their health status.
References


APPENDICES
Appendix A - Copy of Instruments
Product Survey Participant Information

Age: ______ years
Sex: M / F
Academic Major: ______________________

Do you like pudding?
_____ Yes
_____ No

Please check the ONE box in each row that corresponds to how frequently you consume…

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>Less than once a month</th>
<th>Once a month</th>
<th>2-4 times a month</th>
<th>2-6 times a week</th>
<th>7 or more times a week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any dessert</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pudding</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Vanilla Pudding</td>
<td></td>
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</table>

***THANK YOU FOR YOUR HELP WITH THIS STUDY!***
Consumer Survey for Pudding

Product Rating

Please rate this pudding on the following characteristics:

**APPEARANCE**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td></td>
<td>Extremely Dislike</td>
<td>Neutral</td>
<td>Extremely Like</td>
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**SMELL**

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**CREAMINESS**

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**FLAVOR**

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**AFTERTASTE**

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**OVERALL ACCEPTABILITY**

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**WOULD YOU PURCHASE THIS PRODUCT?**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
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<th>3</th>
<th>4</th>
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<th>7</th>
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<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Definitely No</td>
<td>Neutral</td>
<td>Definitely Yes</td>
<td></td>
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</table>
Appendix B: Institutional Review Board Approval and Informed Consent
After a review of your proposed research project numbered H20125 and titled "Sensory Measures of Vanilla Pudding following Replacement of Corn Starch or Tapioca with Kuzu Starch," it appears that your research involves activities that do not require full approval by the Institutional Review Board (IRB) according to federal guidelines. In this research project research data will be collected anonymously.

According to the Code of Federal Regulations Title 45 Part 46, your research protocol is determined to be exempt from full review under the following exemption category(s):

Exemption 6 Taste and food-quality evaluation and consumer acceptance studies if wholesome foods without additives are consumed or a food is consumed that contains food ingredients at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA (Food and Drug Administration) or approved by the EPA (Environmental Protection Agency) or Food Safety and Inspection Service of the USDA (Agriculture).

Any alteration in the terms or conditions of your involvement may alter this approval. Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that your research, as submitted, is exempt from IRB approval. No further action or IRB oversight is required, as long as the project remains the same. If you alter the project, it is your responsibility to notify the IRB and acquire a new determination of exemption. Because this project was determined to be exempt from further IRB oversight, this project does not require an expiration date.

Sincerely,

Eleanor Haynes
Compliance Officer
Institutional Review Board (IRB)
Application for Research Approval – Exemption 6

For Office Use Only: Protocol ID

Principal Investigator
PP’s Name: Carlise英格曼
Phone: 404-901-2767
Email: c80763@georgiasouthern.edu

Department: Health Sciences and Kinesiology
College: WCSP

Primary Campus: Statesboro Campus
Other Campus: Armstrong Campus, Liberty Campus

Faculty □ Doctoral □ Specialist □ Masters □ Undergraduate □ Other:

Georgia Southern Co-Investigator(s)
Co-1’s Name(s): Dr. Joelle Romanchik-Cerpowicz, RD, LD (F)
Angel Rosner (U)

Email: jromchik@georgiasouthern.edu
sir99925@georgiasouthern.edu

(Note: Georgia Southern email addresses will be used for all correspondence.)

Personnel and/or Institutions Outside of Georgia Southern University involved in this research:
□ None
□ Training Attended □ IRB Approval Attained □ Intent to rely on GS
□ Training Attended □ IRB Approval Attained □ Intent to rely on GS

Project Information
Title: Sensory Measures of Vanilla Pudding following Replacement of Corn Starch or Tapioca with Kuzu Starch
Number of Subjects (Maximum) 300

Will you be using monetary incentives (cash and/or gift cards)? □ Yes X No

Funding Source: □ Federal □ State □ Private □ Internal GS (enter source below) □ Self-funded/non-funded
Funding Agency/ GS Source: Grant Number:

Grant Title: □ Same as above □ Enter here:

Compliance Information
Do you or any investigator on this project have a financial interest in the subjects, study outcome, or project sponsor? (A disclosed conflict of interest will not preclude approval. An undisclosed conflict of interest will result in disciplinary action.) □ Yes X No (If yes attach disclosure form)

Certifications
I certify that the statements made in this request are accurate and complete, and if I receive IRB approval for this project, I agree to inform the IRB in writing of any emergent problems or proposed procedural changes. I agree not to proceed with the project until the problems have been resolved or the IRB has reviewed and approved the changes. It is the explicit responsibility of the researchers and supervising faculty/staff to ensure the well-being of human participants. At the conclusion of the project I will submit a report. A report must be submitted no later than 12 months after project initiation.

Signature of Primary Investigator

Date 10/7/2019

Signature of Co-Investigator(s)

Date 10/7/19

By signing this cover page I acknowledge that I have reviewed and approved this protocol for scientific merit, rational and significance. I further acknowledge that I approve the ethical basis for the study.

If faculty project, enter department chair’s name; if student project, enter research advisor’s name: Dr. Joelle Romanchik-Cerpowicz

Signature of Department Chair or Research Advisor

Date 10/7/2019
Institutional Review Board (IRB)
Application for Research Approval – Exemption 6

Instructions: Please respond to the following as clearly as possible. The application should include a step by step plan of how you will obtain your subjects, conduct the research, and analyze the data. Make sure the application clearly explains aspects of the methodology that provide protections for your human subjects. Your application should be written to be read and understood by a general audience who does not have prior knowledge of your research and by committee members who may not be an expert in your specific field of research. Your reviewers will only have the information you provide in your application. Explain any technical terms, jargon or acronyms. Read the entire form before beginning to limit repetition in responses.

Exemption 6 – Taste and food quality evaluation and consumer acceptance studies
(i) If wholesome foods without additives are consumed or
(ii) If a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural
chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or
approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of
Agriculture. (46 CFR 45.164 (d)(6))

1. Personnel

Please list any individuals who will be conducting research on this study. Also, please detail the experience, level of involvement in the
process, and the access to information that each may have.

Carissa Ingram – Nutrition and Food Science Undergraduate – Junior NTS student with basic food science experience desiring to
complete a University Honors Program Thesis
Angel Rossier – Nutrition and Food Science Undergraduate – Junior NTS student with basic food science experience desiring to gain
more research experience
Joelle Romanchik-Czepkowski, PhD, RD, LD – Faculty in NTS with multiple research publications in food product development and
experience testing new food products with consumer panels

2. Project description

A. Briefly describe in one or two sentences the purpose of your research.

The purpose of this research is to determine the consumer acceptability of vanilla pudding prepared with either corn, tapioca, or kuzu
food starch as the thickener.

B. Describe the research project elements in sufficient detail to allow reviewers to understand your project. Clearly and briefly
describe the methods you will use in terms of what participants will be asked to do and how the data will be handled.

Kuzu is a Japanese root vegetable which contains considerable starch. As such, like corn and tapioca starch, it has thickening and
gelling capabilities in food products. While corn and tapioca starch are most commonly used for thickening and gelling foods such as
puddings and gravies, the acceptability of lesser known starches, such as kuzu, in pudding is not known, especially its acceptability
compared to more well-known starches such as corn or tapioca. This research has the potential to expand options for food based
thickeners in the food industry and provide a value added use for kuzu. Puddings will be prepared with similar weights of each food
starch and consumers will rate their acceptability on appearance, smell, creaminess, taste, aftertaste, and overall acceptability as well
as their willingness to purchase each product. Data will remain anonymous as the consent letter will be separate from each
participant’s consumer surveys.

C. Document and describe the concentration levels of all specific compounds tested in this research to demonstrate they are
below FDA Generally Recognized as Safe (GRAS) and accepted exposure limits for human consumption.

The vanilla puddings in this study are derived from a recipe published in “Foods: Experimental Perspectives, 9th edition by McWilliams
(Pearson Publishing Co., 2017). The following foods may be ingredients in the vanilla puddings to be tested in this study: granulated
sugar, milk, vanilla, butter, corn starch, kuzu starch, or tapioca starch. All ingredients are normal foods, will be tested in 0.5 g to 500 g
quantities, typical of existing vanilla puddings or other starch thickened products currently on the market and given FDA Generally
Recognized as Safe (GRAS) status.

D. Describe how you will protect the quality of the food. Include location and safeguards for food preparation, temperature
maintenance, and sanitation in sample delivery.

All products will be produced in a HACCP-controlled facility (Experimental Food Science Laboratory – Room 3031/Interdisciplinary
Classroom Building on the Statesboro campus of Georgia Southern University). Therefore, as consistent with other similar puddings,
products will be promptly cooled to 40 degrees Fahrenheit and stored under refrigerated conditions in sealed containers and served
within three days of preparation. In addition, cross contamination prevention measures, common to foodservice facilities, including
post-preparation sanitation with a 10% (v/v) bleach solution, will be used to prevent food borne illness.

E. Describe how data will be gathered without identifying participants in data collection directly or through codes or
demographic information linked to the data or how participant privacy will be preserved.

The identity of the participants will be protected by the use of numerical and alphabetical codes on surveys which will solely link one
### Institutional Review Board (IRB)

**Application for Research Approval – Exemption 6**

Participant's survey with subsequent surveys completed by a particular participant for each of the products tested in this study. No name or other identifying markers will appear on any of the surveys used in this study.

**F. Describe how you will account for potential food allergies.**

The cover letter states that participants with food allergies should not take part in the study. These individuals will not be served the products to be tested in this study.

**G. Are participants:**
- ☑️ Over 18
- ☐ Under 18

If under 18, how will you obtain parental permission for this study?

N/A

**H. Describe how you will analyze and the format in which you will report data**

Data will be analyzed as means and standard deviations of the acceptability of sensory characteristics described in the attached sample survey. Data will not be recorded with any name identification.

---

### 3. Describe Your Subjects

**A. Briefly describe the study population.**

The study population will include consumers of puddings among a college population of faculty, staff, and students all over the age of 18.

**B. Applicable inclusion or exclusion requirements (ages, gender requirements, allergies, etc.)**

Volunteers over the age of 18 will be included in the study without further regard to their age or gender. Any participant indicating a food allergy on the consent letter will be excluded from the study.

**C. How long will each subject be involved in the project? (Number of occasions and duration)**

Taste testing will be conducted in one tasting session estimated to take approximately 20 minutes to complete.

---

### 4. Recruitment and Incentives

**A. Recruitment.** Describe how subjects will be identified and recruited. (Attach a copy of recruitment emails, flyers, social media posts, etc.)

Faculty, staff, and student volunteers (n=300), all over the age of 18, will be recruited throughout the Georgia Southern University, Statesboro campus. More specifically, Dr. Romanchik (Co-Investigator) will obtain permission to recruit from Nutrition and Food Science courses by asking colleagues if the other investigators on this IRB approval application may make an announcement about the study and a call for volunteers in their classes. Specifically, an announcement will be made in Nutrition and Food Science courses asking for volunteers to taste test the products. Those voluntarily wishing to participate in the study will be asked to come to Room 3030 in the IAB (Experimental Food Science Taste Testing Laboratory—a facility that adheres to HACCP procedures) where the testing will take place. Participants will be asked of their willingness to participate in the study. If willing, they will sign a letter of agreement to participate (see attached) and barring any food allergies (also asked on the letter—see bottom), they will taste-test and evaluate food product samples developed in this study. Each participant will evaluate each product up to two times. Any volunteer with food allergies will be excluded from the study.

**B. Are you compensating your subjects with money, course credit, extra credit, or other incentives? (see GS human subjects incentive policy)**

- ☐ Yes
- ☑️ No

**C. If yes, indicate how much, how incentives will be distributed, and describe if you will compensate subjects who withdraw from the project before it ends.**

N/A

---

### Attachments

- ☑️ Consent letter attached. (See Informed Consent checklist for criteria)
- ☑️ Informed consent or element of consent waiver requested
- Attach the Waiver Request form (Complete Table 1 for complete waiver and Table 2 for alteration of one or more elements)
- ☑️ Letter of cooperation attached for locations where participants or data will be accessed. (E.g., public school, hospital, business, open market, festival, Russell Union, RAC, campus food service locations. If walk up solicitations – see public access research guidelines on the IRB website, etc.)
- ☑️ LOC Waiver Requested (Attach the Waiver Request form. Complete Table 3)
This is to certify that:

Carissa Ingram

Has completed the following CITI Program course:

Human Subjects-Social & Behavioral Research - Basic/Refresher (Curriculum Group)
Human Subjects-Social & Behavioral Research - Basic/Refresher (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

Georgia Southern University

Verify at www.citiprogram.org/verify/w163b9f05-2d97-4572-838e-abcecc0e43363-33548194
This is to certify that:

Angel Rosser

Has completed the following CITI Program course:

- Human Subjects-Social & Behavioral Research - Basic/Refresher
- Human Subjects-Social & Behavioral Research - Basic/Refresher

1 - Basic Course

Under requirements set by:

Georgia Southern University

Verify at www.citiprogram.org/verify/?w5005b1d8-bf67-40d1-b858-a50fc5d661ea-33560195
This is to certify that:

Joelle Romanchik-Cerpovicz

Has completed the following CITI Program course:

Human Subjects-Social & Behavioral Research - Basic/Refresher (Curriculum Group)
Human Subjects-Social & Behavioral Research - Basic/Refresher (Course Learner Group)
3 - Refresher Course (Stage)

Under requirements set by:

Georgia Southern University

Verify at www.citiprogram.org/verify/?w665335cc-b1a8-4c84-bf5a-ed8a2450cd76-32318311
Appendix C: Time Schedule of Study
Appendix C: Time Schedule of Study

Submit IRB Forms

Data Collection

Data Analysis

Thesis Proposal Drafted

Thesis Proposal Submitted

Submit Final Draft of Thesis to Mentor

Presentation of Thesis

October 2019

September-December 2019

January- March 2020

March 2020

May 2020

April 2021

April 2021
Appendix D: Biography
Appendix D: Biographical Summary

Carissa Destiny Ingram  
Date of Birth: November 6, 1998

Home Address:  
2575 Betty Sue Drive Buford, GA 30519

Georgia Southern University:  
2017-2021

Bachelor of Science:  
Nutrition and Food Science

Emphases:  
Dietetics

Thesis Title:  
*Substitution of Kudzu Starch for Cornstarch Results in Dairy-Based Vanilla Pudding with Similar Texture and Consumer Acceptability.*

Mentor: Dr. Joelle Romanchik-Cerpovicz