Measurement and Intervention:

Two Projects to Address Malnutrition and Its Effects in Guatemala

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Abstract

Stunting in Guatemala has an unacceptably high prevalence as a result of a long history of malnutrition. Nutritional research is interested in the measurement of the effects of stunting on the body and the avoidance of this devastating condition which causes substantial economic losses to the nation and is detrimental to healthy physical, social, and intellectual development. This study had two parts in order to address the two primary components of nutritional study: measurement and intervention. The first objective was to determine the strength of the correlation, and thus efficacy, of sagittal (side-view) photography to measure body ratios, specifically the proportion of trunk length in relation to leg length, to the physical measurement system which is currently the standard practice. Sagittal photography, if accurate, would provide a much more efficient and less intrusive form of measuring stunting in large-scale data collection of indigenous populations for stunting research. We determined that only weak correlation exists, with a much less than 1:1 ratio, between the two systems for the ratios of interest, trunk-to-leg ratio, trunk-to-height ratio, and leg-to-height ratio. Thus, the use of sagittal photography fails to provide an adequate form of efficient measurement of body proportions.

The second half of the study explored potential solutions to the nutritional deficits that have lead to the stunting epidemic in Guatemala through a survey and sensory panel to determine the palatability and acceptability of various liquid vehicles for nutritional supplementation. This analyzed the potential of cream soups, milk-based smoothies, and cold soups to be effective vehicles for a six-gram whey-protein supplement and increased water intake, particularly for Guatemalan women whose nutrition during pregnancy and lactation lays the foundation for the long-term health of their child. Our study concluded that cream soups have the highest potential

as a successful supplementation vehicle, while milk-based smoothies face a cost barrier that inhibits their use as a supplement, and cold soups are too foreign to Guatemalan culture.

Both studies compiled data collected in June and July of 2017 and 2018 to produce statistical robustness with a large data set. Consequently, the study was able to evaluate consistency of results between years, particularly for the responses to the survey of background knowledge on liquid vehicles. The results were remarkably consistent on corresponding questions in the 2017 and 2018 surveys, indicating that results produced are likely reflective of the community surveyed.

Introduction

Malnutrition is a far-reaching problem that affects communities around the world and manifests in economic and physical repercussions for both individuals and society as a whole. Malnutrition is not simply a result of too little food, but rather a consequence of inadequate nutrition—which can stem from an unbalanced diet, inadequate nutrient intake, disproportionate consumption of empty calories, or the typical image of insufficient food availability. The impact of malnutrition is intangibly large, affecting the affected individuals' own growth and development, but also leading to similar devastating consequences for their offspring, loss of economic productivity, and reduced ability to contribute to society.

Physically, malnutrition can lead to stunting (height for age ratio more than two standard deviations below median ratio in reference population (UNICEF, n.d.)), wasting (weight for height ratio more than two standard deviations below median ratio in reference population (UNICEF, n.d.)), obesity (Body Mass Index, a method of measuring weight for height ratio, greater than 30 (Centers for Disease Control, 2016)), and many other growth issues.

In Guatemala, malnutrition has led to an overwhelming prevalence of stunting in the population, often coupled with obesity— a pairing that reflects the consumption of excess calories from a diet which does not contain adequate nutrition with a proper balance of protein, carbohydrates, fats, vitamins, etc. to sustain a person.

Stunting has become an epidemic in Guatemala, with a rate of 46.5% in children under the age of five nationally. In some regions of Guatemala, such as Totonicapán, the rate of stunting in this age group reaches as high as 70.0% (USAID, 2016). Although it is easy to overlook this issue as a genetic lack of height when stunting manifests with such frequency in the population, it is truly a reflection of malnutrition that has dramatic health and economic impact.

In fact, in 2004, it was estimated that 11.4% of the national GDP, or $3.1 million, was lost annually due to the loss of productivity associated with malnutrition (The World Bank, n.d.). Furthermore, malnutrition increases a child's susceptibility to death or severe health consequences from common childhood illnesses, increases the likelihood of the development of cardiovascular conditions, curtails cognitive development, and altogether diminishes the affected individuals' life economic productivity, physical and mental capabilities, and life expectancy (USAID, 2016).

With such dramatic effects on the individual and the nation as a whole, stunting is a critical issue to study and resolve in Guatemala. Although nutrition throughout an individual's life is relevant, there are certain periods that have critical importance in growth and development. In particular, the mother's nutrition before conception and the child's nutrition in the first 1,000 days of life (beginning at conception through the first two years of life) play a vital role in their later physical and cognitive development. Despite increasing quantities of research to document the multitude of later impacts of nutrition in the first 1,000 days of life, including irreversible growth and cognitive retardation, lack of education and resources have led to inadequate water and nutrient intake of Guatemalan women during pregnancy and lactation. One study conducted in the Western Highlands region of Guatemala documented deficits in protein intake of Guatemalan women of up to 19 g daily (Escobar et. al., 2017), out of the recommended 26 g of protein consumption in the third trimester of pregnancy and the recommended 21g of protein daily in the first semester of breastfeeding (Marangoni et. al., 2016). To the further detriment of the growing infant, studies have also shown water intake by Guatemalan women to frequently fall short of adequacy by as much as one liter per day during this critical stage, leading to hypohydration (Diaz--Jereda, 2017). Together, these factors lead to the very early manifestations

of chronic malnutrition, or stunting, which are present throughout the nation and necessitate intervention.

Consequently, potential vehicles for expanding the reach of current nutritional intervention attempts in Guatemala are a primary research focus, particularly those suited to the needs and taste preferences of Guatemalan women whose nutrition has a trickle-down effect to the growth and development of their children. Current practices concentrate on nutritional fortification of the typical Guatemalan beverages 'atoles' which are thin gruel drinks (Escobar et. al., 2017). Offering expanded options which also conform to dietary preferences is one targeted method for increasing the efficacy of programs which aim to improve protein and water consumption of Guatemalan pregnant and lactating women. As a culture of soup and smoothie consumption is known to exist in Guatemala, this study investigated the acceptability to Guatemalan women of three cream soups, three cold soups, and three milk-based smoothies with added whey protein fortification. The success of these three options is hypothesized to be as follows: 1) cold soups are not commonly consumed by Guatemalan woman and are thus unlikely to be a feasible vehicle for protein supplementation, but still worth exploring as a possible option; 2) Milk-based, protein enhanced smoothie will conform to the familiar palate of Guatemalans, but will unlikely be a feasible vehicle for protein supplementation due to the preference towards water-based smoothies; and 3) Creamy soups will provide the best vehicle for protein supplementation of Guatemalan women, as they are already part of the typical diet and will be texturally and flavor enhanced by the addition of the protein supplement.

Although nutritional intervention and education are critical to reversing the issues which face the people of Guatemala and other malnourished communities globally, there is also significant scientific interest in knowing the specific effects of stunting and malnutrition on the

body, its systems, and its growth. This will allow future studies to ensure accuracy when measuring the impact of nutritional interventions and other efforts to reduce the prevalence of stunting, as a specific metric for which body proportions are affected will be known. Current studies show that the loss of height in stunting occurs in the legs, rather than the trunk, as the body prioritizes resource distribution to the vital organs which are housed in the trunk (Shiu, 2016). An efficient, minimally intrusive method of data collection is needed to collect large data sets in many populations to confirm these results and allow further study of body proportions. Physical measurement of height and sitting height are much more time consuming than taking a sagittal photograph. Thus, if the body proportions measured within a sagittal photograph strongly correlate with those measured physically, photography would be a much superior method for data collection in the field. Determining the accuracy of the sagittal photograph with respect to the physical measurements is the second goal of this study. It is hypothesized that measurements of sagittal photography will produce body proportions which strongly correlated with those produced by physical measurements. Secondarily, data collected to compare the two measurement systems can also be used to compare the body proportions of non-Guatemalans, who are known to be taller on average, to Guatemalan people to further analyze how various body proportions vary with the height reduction.

Both projects build on past work by CeSSIAM in order to produce more statistically robust results and expand the focus of research. The supplementation project built on several past years of research into appropriate vehicles. Several years ago, Incaparina, as mentioned earlier, was identified as a potential source of supplementation (Platte, 2016), as well as supplementation of Atol (Escobar 2016). Last year, research was conducted to explore the use of cream soups and to gain a general understanding of the Guatemalan women's background knowledge on various

liquid vehicles. This year, the study conducted a second survey to confirm and add to the information gathered in 2017 (Dougherty, 2017) and performed sensory panels for two more possible liquid vehicles— cold soups and milk-based smoothies— as well as additional flavors of cream soups. Past data collection for the sitting height project primarily focused on data collection for females (Shiu, 2016; Silverhus, 2017). Thus, to create a more demographically even distribution of the studied population, 2018 data collection focused on the recruitment of male participants, aiming to also balance the number of non-Guatemalan and Guatemalan people measured.

Methods

I. Participants

Participants were recruited at the entrance of Nim P'ot Market in Antigua, Guatemala. The inclusion criteria for participants were that they were at least 18 years old, able to walk, able to stand erect, and fluent in either English or Spanish. In order to meet the sample size target in 2018, an additional requirement for participants to be male was added.

Participants of the sensory panel studies were residents of surrounding communities, recruited at Nuestros

		Measured 2017	Measured 2018	Measured in Total
Women	Guatemalan	64	0	64
	Non-Guatemalan	63	0	63
Men	Guatemalan	17	42	59
	Non-Guatemalan	30	58	88
	Total	174	100	274

Figure 1. ***Participant demographics and sample size in sitting height study***

		Age in Years		
	N	Mean ± SD	Median	Min — Max
Creamy Soup Survey	26	28.2 ± 14.2	27	12 — 64
Creamy Soup Trial	25	27.6 ± 14.2	27	12 — 64
Cold Soup Survey	46	44.0 ± 15.9	41.5	15 — 80
Cold Soup Trial	19	40.8 ± 15.8	41	15 — 70
Smoothie Survey	46	44.0 ± 15.9	41.5	15 — 80
Smoothie Trial	21	46.3 ± 15.8	42	15 — 80

Figure 2. ***Participant demographics and sample size in 2018 sensory panel studies***

Ahijados Project in Antigua, Guatemala. The inclusion criteria for participants were that they were Guatemalan, female, and fluent in Spanish.

II. Apparatus and Materials

The required materials for the sitting height study were a retractable tape measure, masking tape, a level, a sitting height measurement apparatus (vertical ruler attached to platform seat), a table, a short vertical ruler, an electronic balance, a stool with a dry erase sign, a dry erase marker, stool, camera, camera apparatus, a layout square, consent forms, and writing utensils.

Figure 3. ***Setup for sitting height study. Far left: sitting height measuring apparatus; center left: tape measure height setup; center right: table with pelvic height ruler; far right: electronic balance for weight measurement.***

The sensory panel studies required three varieties of materials: cooking materials, transport materials, and serving materials. The recipes and, thus, required ingredients for each cold soup and smoothie flavor are included in the appendix. The cream soups were prepared with Maggi soup packets and water.

III. Procedure

A. The Efficacy of Sagittal Photography in the Analysis of Body Proportions

a. Experimental design

Analysis 1

Independent Variable: Measurement method used

1) Physical anthropometric measurements

2) Sagittal photograph measurements

Dependent Variable: Body proportions measured

Controlled Variables:

1) Person conducting measurement
2) Tools used for measurement
3) Method used to analyze photograph

Analysis 2

Independent Variable: Demographic background

1) Guatemalan
2) Non-Guatemalan

Dependent Variable: Body proportions

Controls:

1) Measurement system used: physical measurement
2) Likewise to analysis 1

b. Procedure

1) The participant began by completing a consent form and removing all pocket contents, shoes, hats, and other accessories.
2) A series of anthropometric measurements were then taken.
    a) First, the participant stood with his heels against the wall and head in a Frankfort plane gaze by the vertically extended tape measure. A layout square was then used to compress the participant's hair and record a measurement of height to the apex of the head to the nearest 0.5 cm.

b) Second, the participant stood on an electronic balance, facing forward. The weight was recorded in kg as displayed on the scale (to the nearest 0.1 kg). Weight was then adjusted according to clothing worn, with 1 kg subtracted if dressed in heavyweight clothing and 0.45 kg subtracted for light clothing. The weight of the clothing was determined by the pant type being worn, with long pants and jeans deemed heavyweight, and shorts deemed lightweight.

c) Third, the participant was instructed to sit on a table with his right hand placed on his chest, back straight, and head in a Frankfort plane gaze in order to measure pelvic height. A mark was placed at the midpoint between his Iliac crest (apex of hip bone) and lowest rib on his right side. Then, a layout square and vertical ruler were used to determine the height of the mark to the nearest 0.5 cm.

d) The final anthropometric measurement recorded was sitting height. The participant was instructed to sit with his back straight against the vertical ruler on the sitting height platform and his head in a Frankfort plane gaze (looking straight ahead). A layout square was then used to compress his hair and measure his sitting height to the nearest 0.5 cm.

3) A sagittal (side view) photograph was taken for the photographic measurements.

a) The participant stood on a stool, facing to the right with the right edge of his right foot aligned with the front edge of the stool and his head in a Frankfort plane gaze. He then placed his right hand on his chest and a mark was

placed on his Iliac crest. The code on the stool was changed to match the participant code and a vertical photograph was taken by a camera approximately 3 meters away, positioned vertically (attached to a wooden plank at 90 degree angle from floor). The setup is seen above.

4) The sagittal photograph was printed to fill an 8.5 x 11 inch sheet of paper and proportions of the body were transferred onto a translucent piece of vegetable paper for measurement
    a) Translucent vegetable paper was placed over the sheet of paper
    b) A mark was drawn at the apex of the head and at the base of the feet.
    c) Using a ruler, a vertical line was drawn along the erect body
    d) A line perpendicular to this vertical line was drawn at the point of intersection with the washi tape Iliac crest mark on the participant's hip in the photograph
5) The follow body lengths were recorded to the nearest hundredth centimeter with a ruler
    a) Trunk Length: from the Iliac crest perpendicular line to the apex of the head
    b) Leg Length: from the line at the base of the feet to the Iliac crest perpendicular line
    c) Total Height: from the base of the feet to the apex of the head

B. The Exploration of Liquid Vehicles for Nutritional Supplementation

a. Experimental Design

The two-part concept of survey and sensory panel (tasting session) was designed to collect data on both the cultural acceptability and palatability with supplement of the potential liquid vehicle. A standard set of questions were developed to identify likely success in households based on prior knowledge and current frequency of consumption. For the sensory

panel, a typical approach of taste tasting was used, but careful thought was put into developing a procedure to eliminate bias based on soup location on the tray, order tried, prior conceptions, and peer influence. To do remove the influence of soup tray location on study results, a randomization system was developed for soup location on the tray which was presented with a double-blind system by one interviewer conducting the panel with a single participant at a time. Each tray was randomized individually using a roll of a die to randomize order of sample flavors on the tray, as well as position (top versus bottom) of the fortified version of each. First, the location of each flavor of the liquid vehicle was determined: left, middle, or right. Then, the location of the protein was randomized: front or back within the designated column for each flavor. Location of each sample was recorded for each participant to allow analysis of bias based on location and the evaluation of lasting bias. For the second bias of concern— basis based on prior conceptions of the liquid vehicle— a double blind presentation system was used, where neither the interviewer nor the participant were aware of the identities of the samples. Finally, the possibility of bias by peers was controlled for by interviewing a single participant at a time to prevent communication and influence by peer responses to each sample.

Dependent Variable: Presence of protein fortification

1) Standard recipe of liquid vehicle
2) Protein fortified recipe of liquid vehicle

Independent Variable: Perceived Taste

- Two samples the same or different
- Taste preference between samples

Control Variables

1) Participant
2) Method of presentation
3) Base recipe used

Procedure

1) Liquid vehicles are prepared
    a) Cold soups were prepared ahead of time according to recipe (Appendix).
    b) Cream soups were prepared ahead of time by dissolving Maggi cream soup packets into 1 liter of water per packet, boiling for 7 minutes, and stirring. Soup was transported to the site in plastic containers and then heated in a microwave for about three minutes to serve between 40 and 50 degrees Celsius
    c) Smoothies were prepared on site according to selected recipe with fresh fruit of specified variety (Appendix).
    d) After the preparation of each vehicle, produced quantity was divided into two parts and a 6-gram whey protein supplement was stirred into one half.
2) For each sensory panel, the liquid dish was served in a 100 mL portion in a coded plastic cup. The 6 cups were then arranged in a randomized order in a two row, three column grid. Each column represented a single flavor, with one cup offering the protein supplemented version and the other offering the plain version. A roll of a die was used to randomize the order of the three liquid dish flavor columns (left, center, or right) and the respective location of the supplemented version within the column (top or bottom).
3) Participants complete a paper and pen survey about their background knowledge and frequency of consumption of the liquid dish.

4) Participants are divided into three groups
5) Participants are seated at a table and presented with a tray of six samples of one liquid dish type. The interviewer explains the procedure and they begin.
6) The participant is allowed to select which cup is sampled first. They take three sips of the sample and then drink water.
7) The participant is instructed to try the other sample in the column (the pair to the one first selected).
8) The participant is allowed to retry either of the two samples but is not required to finish the provided amount. They then give their feedback to the interviewer, indicating whether they tasted a difference between the two samples, which sample they preferred, and whether they liked the samples.

Results and Discussion

A. The Efficacy of Sagittal Photography in the Analysis of Body Proportions

With the high prevalence of stunting in Guatemala, a central concern of research is the development of an efficient, standardized approach to measuring its effects on growth and body proportions. Although physical measurement of sitting height, total height, and pelvic height has been a long-accepted option, a more efficient, less intrusive option is desired to allow larger-scale data collection within the indigenous populations of Guatemala without huge time expenditure or cost. Thus, sagittal photography was proposed as a minimally intrusive form of measurement to accomplish this goal. The hypothesis, building off of preliminary data collection in 2017, was that photographic measurement would produce strong correlation with physical measurement with an approximate 1:1 relationship in measured body ratios. This hypothesis was

rejected upon analysis of the compiled 2017/2018 data set which indicated a less complete correlation, where, for most body ratios, the two systems of measurement only weakly correlated and had less than a 1:0.3 relationship of physical: photographically measured ratios. A second goal of the project was to compare the body ratios of Guatemalans to those of non-Guatemalans, made possible by the large-scale data collection of body proportion data for both populations in order to determine the efficacy of the sagittal photography in measurement of body ratios. The hypothesis, developed from past research which suggests that stunting results in disproportionate loss of leg length in its characteristic loss of height, was that, not only would the Guatemalan population be significantly shorter than the non-Guatemalan population, but the Guatemalan population would have significantly higher trunk-to-leg ratios than the non-Guatemalan population. This was confirmed by the data in both the men and women populations.

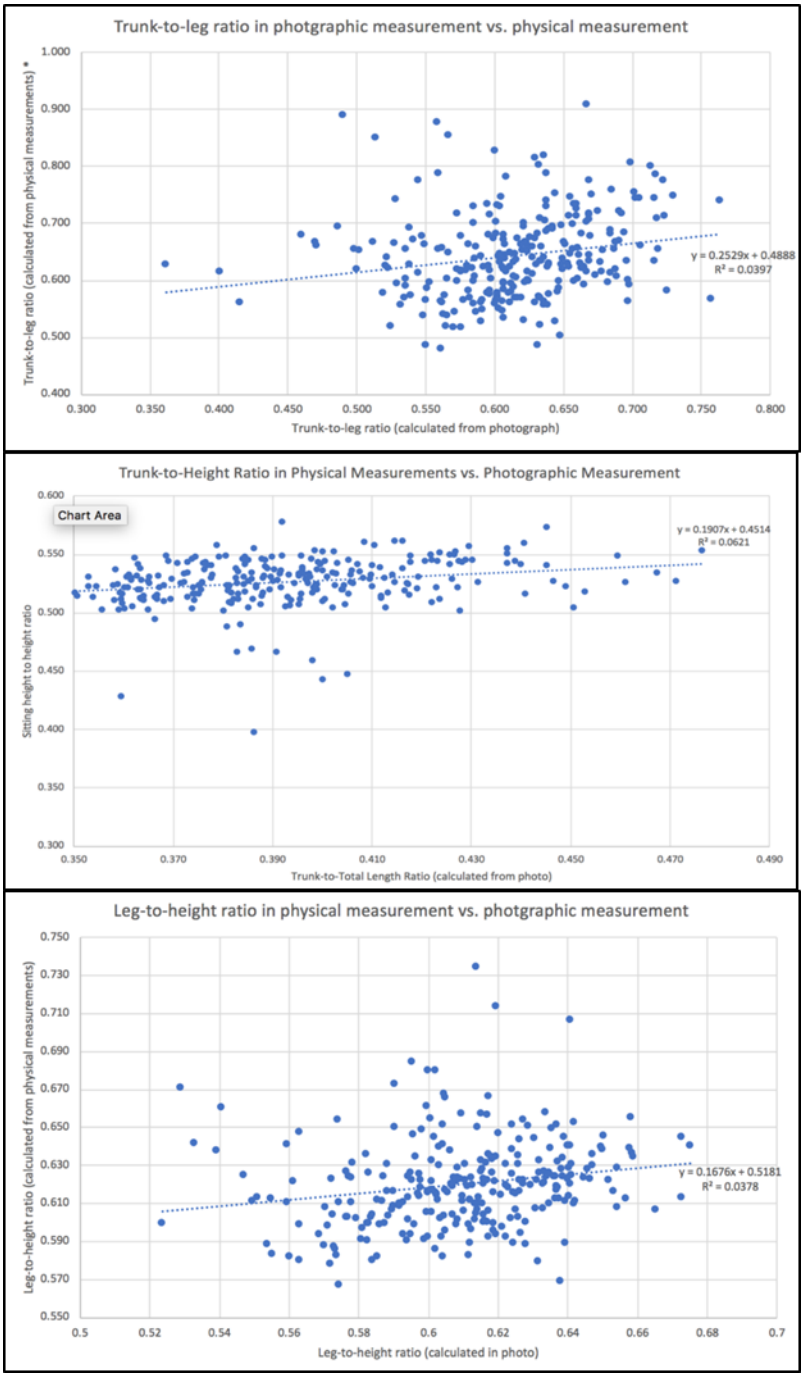


Figure 4. ***The relationship between photographic and physical measured ratios for trunk-to-leg (top), trunk-to-height (middle), and leg-to-height (bottom) ratios***

The three body ratios of interest were trunk-to-leg ratio, trunk-to-height ratio, and leg-to-height ratio. All three displayed a weak correlation between the physical and photographic measurement, with Spearman Correlation Coefficients of 0.274, 0.305, and 0.272. All p-values indicated the correlation was significant, with p=4.11 e -6, 2.66 e -7, and 4.99 e -6 (significance at 0.05 level). Figure 4 shows each of these correlations. As seen in the graph, the photographic measurement not only correlated weakly, but the ratio of the ratios produced by physical measurement to the photographic measurement was not near 1:1 as desired. Instead, it was 0.2529, 0.1907, and 0.1676, respectively.

Interestingly, the absolute measurement of sitting height, back calculated from the photograph, produced a strong correlation with the physical measurement of sitting height (significant Spearman's Correlation Coefficient of 0.564; p-value 2.23 e -24) and a better slope of the trend line (0.5803) between the two systems' results. This may be because to produce the absolute measure from the photograph, unlike the with the body ratios, a physical measurement of height is required (calculated photo trunk length/ photo total length * physical total height). This may be the source of the stronger correlation, as physical measurement is factored into the produced result. Further, this strong correlation holds little significance in implementation of the photographic measurement system as a more efficient, less intrusive means of analysis of stunting because it still requires physical measurement to be taken.

Although the first hypothesis about the efficacy of the sagittal photographic measurement failed to hold true, the physical measurements collected confirmed the second hypothesis which compared the body proportions of the Guatemalan and non-Guatemalan populations.

		Height (cm)				Weight (kg)				BMI			
		Mean ± SD	Median	Min-Max	P-Value	Mean ± SD	Median	Min-Max	P-Value	Mean ± SD	Median	Min-Max	P-Value
Women (n=127)	Guatemalan (n= 64)	151.8 ± 7.2	151.3	140.5 - 169.5	<0.001	61.4 ± 11.7	59.5	34.0 – 101.0	0.711	26.7 ± 4.6	26.8	16.6 – 40.4	<0.001
	Non-Guatemalan (n= 63)	164.5 ± 6.4	164.0	152.0– 182.0		60.4 ± 9.3	59.3	44.2 – 84.5		22.3 ± 3.2	22.3	16.5 – 29.8	
Men (n=147)	Guatemalan (n= 59)	165.7 ± 8.4	166.0	148.0 – 186.0	<0.001	72.3 ± 12.7	71.0	51.6 – 103.0	0.002	26.4 ± 4.7	25.5	18.1 – 41.2	0.033
	Non-Guatemalan (n= 88)	178.7 ± 8.3	179.0	150.0 – 195.5		78.7 ± 12.4	77.8	46.6 – 121.5		24.7 ± 3.8	24.4	15.6 – 34.4	

Figure 5. ***Comparison of height, weight, and BMI between Guatemalans and Non-Guatemalans in both female and male populations***

As seen in Figure 5, Guatemalan people showed a statistically significant lower height, but higher BMI in both males and females, with p-values of <0.001 for both genders in height, <0.001 for men in BMI, and 0.033 for women in BMI (p-values generated with independent samples Mann Whitney U test). Although sitting heights for Guatemalans were also lower than those of non-Guatemalans ($p<0.001$), all three ratios used to compare relative trunk and leg length show that the Guatemalan population has relatively longer trunks in comparison to leg length. In figure 6, a comparison of Guatemalan and Non-Guatemalan women and men is displayed for each of the three measurements. Orange ovals denote a p-value which meets the threshold requirement for the difference between the two groups to be considered significant, which held true for the comparisons for all three ratios in both females and males. The distribution of data is not skewed, thus the mean can be used to accurately represent the center for each population.

Trunk-to-Leg Ratio – Physical Measurement

		Mean ± SD	Median	Min-Max	P-Value
Women (n=127)	Guatemalan (n= 64)	0.619 ± 0.057	0.617	0.486 – 0.764	0.008
	Non-Guatemalan (n= 63)	0.593 ± 0.046	0.599	0.502 – 0.684	
Men (n=147)	Guatemalan (n= 59)	0.650 ± 0.058	0.654	0.401 – 0.757	<0.001
	Non-Guatemalan (n= 88)	0.602 ± 0.059	0.605	0.362 – 0.698	

Leg-to-Height Ratio – Physical Measurement

Mean ± SD	Median	Min-Max	P-Value
0.619 ± 0.022	0.618	0.567 – 0.673	0.008
0.628 ± 0.018	0.625	0.594 – 0.666	
0.607 ± 0.023	0.604	0.569 – 0.714	<0.001
0.625 ± 0.025	0.623	0.589 – 0.734	

Sitting height-to-Total height ratio Physical Measurement

Mean ± SD	Median	Min-Max	P-Value
0.54 ± 0.01	0.54	0.50 –0.58	<0.001
0.53 ± 0.01	0.53	0.50 – 0.56	
0.53 ± 0.01	0.53	0.49 – 0.56	<0.001
0.51 ± 0.02	0.51	0.40 – 0.55	

Figure 6. ***Comparison between trunk-to-leg, leg-to-height, and sitting height-to-total height ratios between Guatemalans and non-Guatemalans in female and male populations***

Having compiled the data from 2017 and 2018 data collection to achieve a large sample size with relatively balanced proportions of males versus females and Guatemalans versus non-Guatemalans, the analysis is statistically robust and rejects the use of sagittal photography with the Iliac crest marked as an optimal form of body proportion measurement. Additionally, the data from physical measurements taken affirm previous studies' conclusions that stunting results in the loss of leg length rather than trunk length, leading to a higher trunk-to-height ratio in the Guatemalan populations, which have long lineages of people affected by malnutrition and stunting, than in non-Guatemalan populations. Although inter- and intra-observer reliability was not measured in 2018 data collection, the 2017 results, which concluded high precision between observers and measurements, can be assumed to hold.

Minor tweaks on data collection which could be made to enhance efficiency, such as the use of a tripod for the photography, but there is no factor that impinged on the accuracy of data

collection to necessitate further study or data collection on the comparison of sagittal photography to physical measurement. One influence which could have lessened the correlation between the two forms of measurement was that physical measurement of sitting height varies with gluteal (buttocks) thickness, whereas the sagittal photograph's trunk height measurement is not affected by this. Further study could build on this work to analyze alternative methods of photographic measurement for the collection of body proportion data or other ways to effectively conduct large-scale, efficient yet unobtrusive data collection on the effects of stunting on body growth. To build on the second topic of interest, the differences in body proportions between non-Guatemalan and Guatemalan populations, further study could analyze the comparative rate of growth of each body portion (legs, trunk, arms, and head circumference) over the lifetime of individuals in communities with high rates of stunting (such as indigenous Guatemalan communities) to those unafflicted (such as foreign populations).

B. The Exploration of Liquid Vehicles for Nutritional Supplementation

Documentation of protein and water deficiency in the diet of Guatemalan women during pregnancy and lactation create an urgent need for change in order to quell the stunting epidemic in Guatemala, as nutrition from conception through two years old has multiplicative effects on growth and development later in life. Past work has focused on supplementation through the commonly consumed Incaparina and Atol drinks, but exploration of expanded options is important in order to extend the reach of this aid.

The first portion of the project focused on expanding research begun in 2017 on the suitability of various cream soups as liquid vehicles for whey-protein supplementation. Similar

survey questions were posed in the revised 2018 survey, providing an outlet to determine the reproducibility of results.

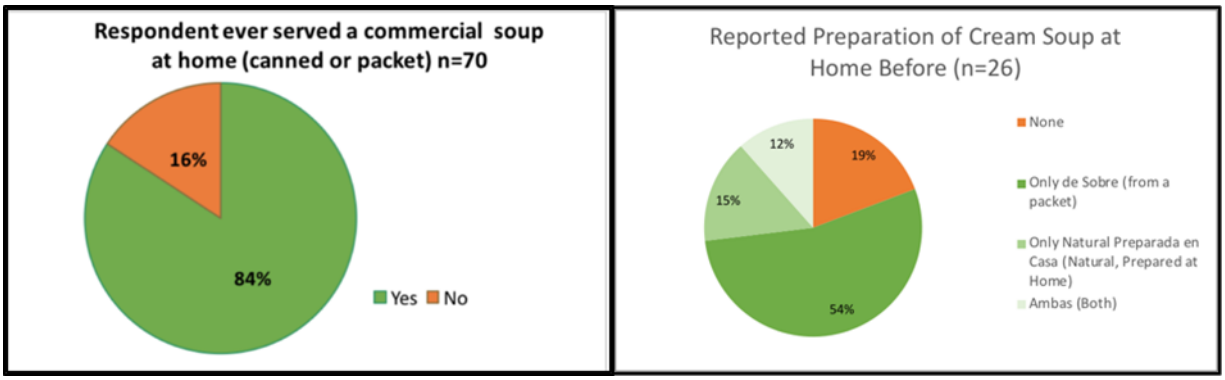


Figure 7. ***The reported preparation of cream soup of Guatemalan women in 2017 (left) and 2018 (right)***

Although expanded options were offered in 2018 to determine methods of common preparation, the breakdown, as seen in Figure 7, between participants responding that they had previously prepared commercial soup at home and those who said they had not were very similar in both studies (84% yes, 16% no in 2017; 81% yes, 19% no in 2018). The consistency of these results is notable and suggests that the results reflect accurately upon the preparation of cream soup by Guatemalan women as a whole.

The 2017 sensory panel study focused on the suitability of the top three mentioned flavors of cream soup from the background survey, but many other flavors were listed by respondents in both 2017 and 2018. Thus, in interest of a diversity of options for Guatemalan women and knowledge of which flavors are most acceptable, 2018 data collection focused on seafood, potato, and spinach cream soups. The data from 2017 and 2018 was then collated and compared to determine the optimal cream soup.

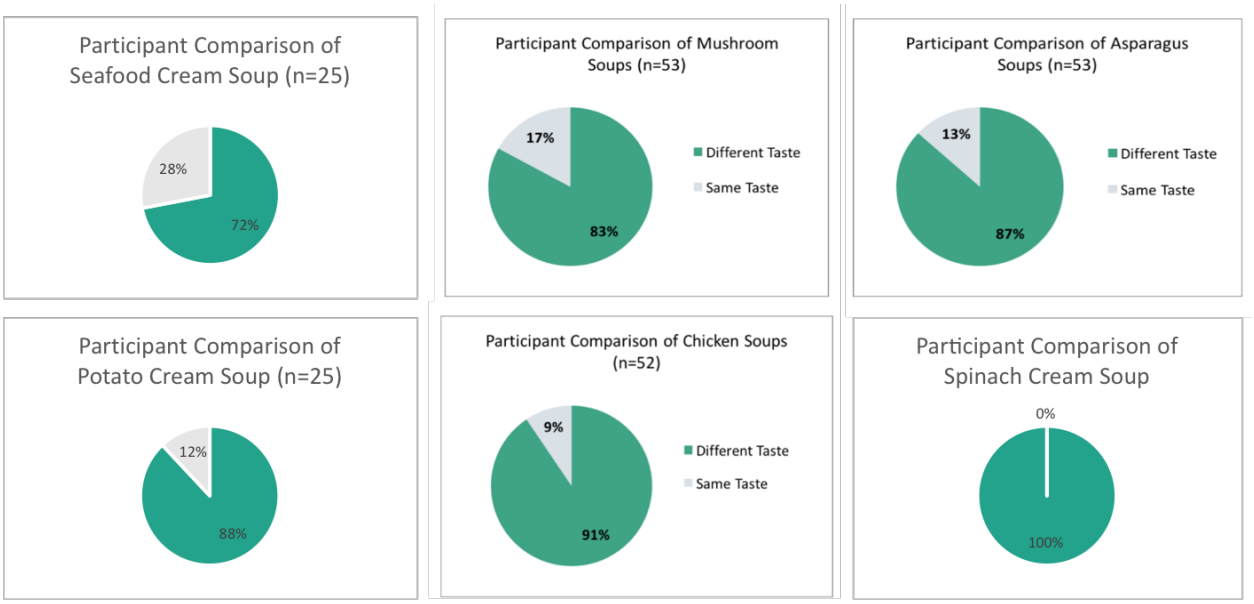


Figure 8. ***The participant comparison of cream soup with and without whey protein supplement***

In Figure 8, it is readily apparent that the addition of whey protein supplement produces a noticeable difference in the flavor of the soups, with 72%-100% of participants, depending on flavor, claiming to notice a difference between the two versions offered. Although optimally no difference would be produced, this is not cause for immediate rejection of cream soups as a vehicle for supplementation because the difference is often perceived as positive, as seen in Figure 9.

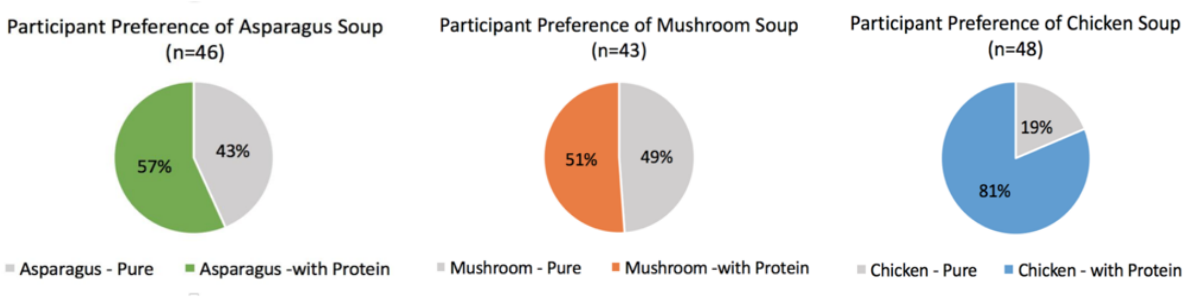
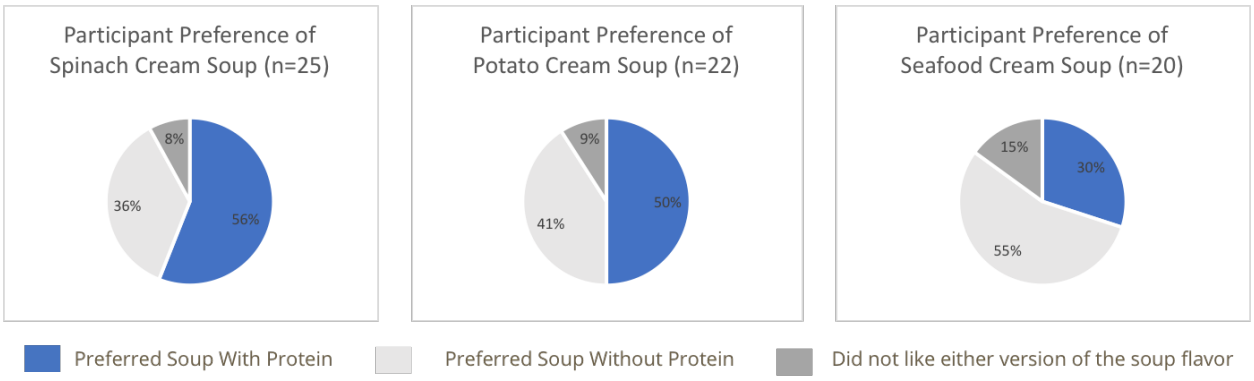


Figure 9. ***The participant preference of each cream soup flavor between protein fortified and plain versions, with 2017 data above (Dougherty, 2017) and 2018 data below***



Of all flavors, the greatest preference for the protein fortified soup was the chicken flavor. Then, in descending order, asparagus (57%), spinach (56%), mushroom (51%), and potato (50%). The only flavor in which more than half preferred the soup without protein was seafood cream soup, which was also had the highest fraction of participants who rejected its taste altogether.

The second sensory panel aimed to explore other options for liquid vehicles. Although the 2017 survey indicated that Guatemalan women have little previous knowledge of cold soups, a sensory panel for cold soups was conducted this year to

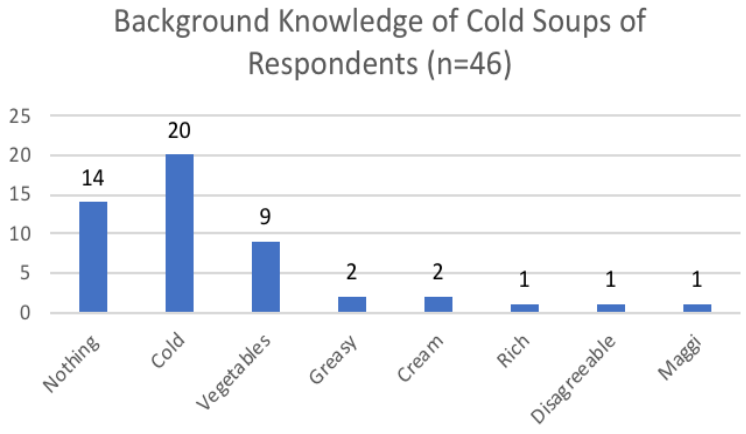


Figure 10. ***Background Knowledge of Cold Soups of 2018 Respondents***

determine if it could be introduced as a novel food of interest with supplementation. The 2018 survey reproduced results very similar to the 2017 survey, showing that 2% of respondents had previously consumed cold soup, compared to 2017's 4%. Additionally, when participants were asked what they think of when they hear 'cold soups', many had very limited background knowledge, as seen below in Figure 10.

The results of the cold soup sensory panel were similar to those of the cream soups, with participants indicating a definite taste difference between the two versions of the soup in all three flavors.

In contrast to cream soups, the difference in taste was not found to be beneficial to palatability, as only slightly less than half of participants indicated a preference towards the protein supplemented version of the soup.

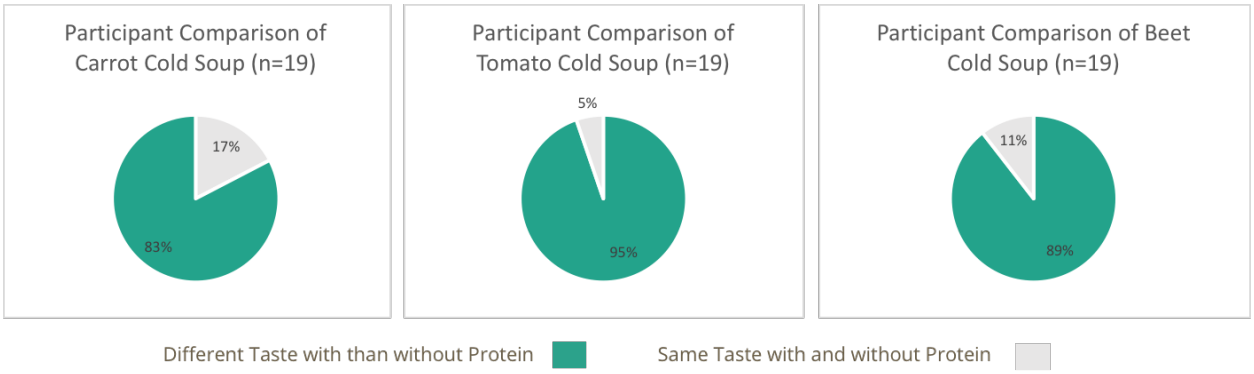


Figure 11. ***Participant comparison of cold soup flavors***

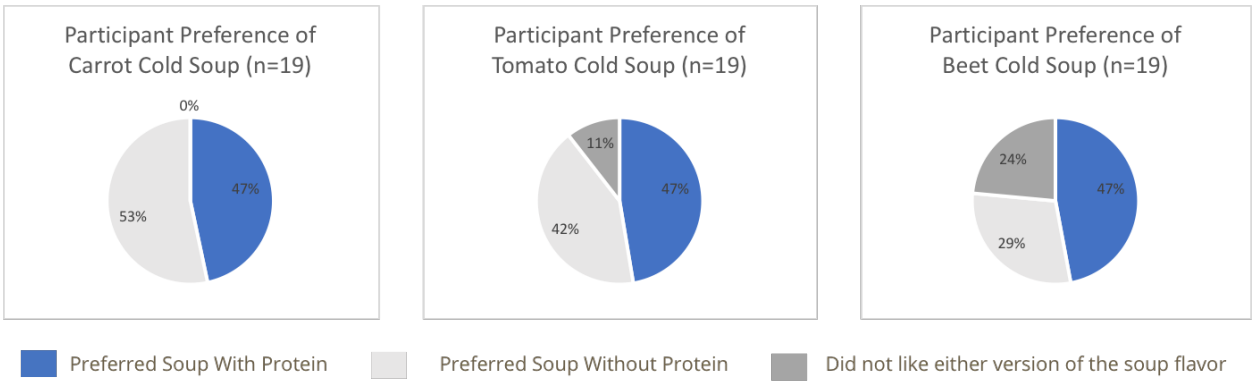


Figure 12. ***Participant preference of cold soup flavors***

The final liquid vehicle studied in the 2018 study was milk-based smoothies. This focus was added in 2018 and, thus, no 2017 data is available for comparison. The first question compared the consumption of smoothies made with water and those with milk because the milk-based smoothie is the compatible with supplementation, whereas the water-based one is not. As seen below in Figure 13, smoothies with water are consumed much more frequently than milk-based smoothie, possibly because of the cost barrier of milk.

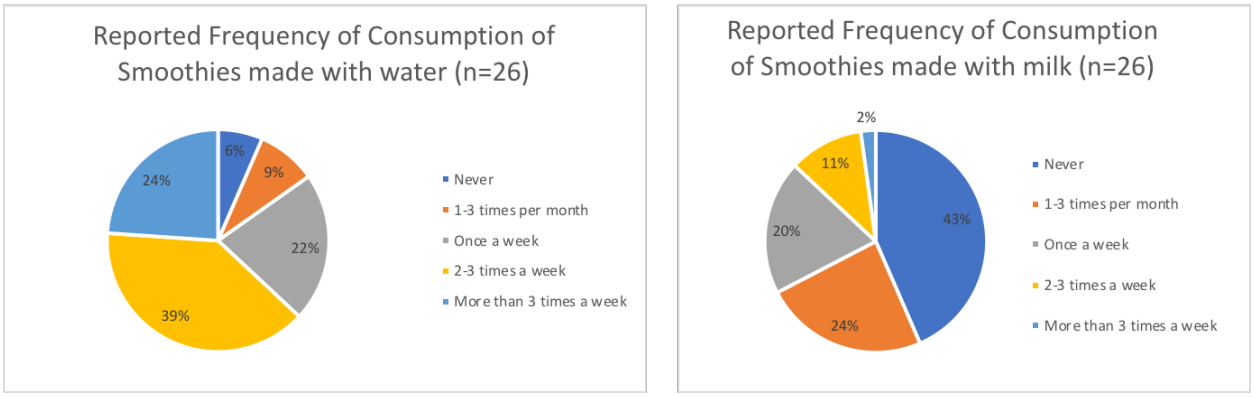


Figure 13. ***Comparison between reported frequency of consumption of smoothies made with milk versus those made with water***

The sensory panel component of the smoothie analysis had similar results to the other two sensory panels. Participants found a difference between fortified and unfortified smoothies, but in banana and strawberry smoothies, this neither added to nor detracted from the palatability of the drink with a roughly 50/50 split of preference. In contrast, most participants preferred papaya smoothies without fortification, as seen in Figure 14.

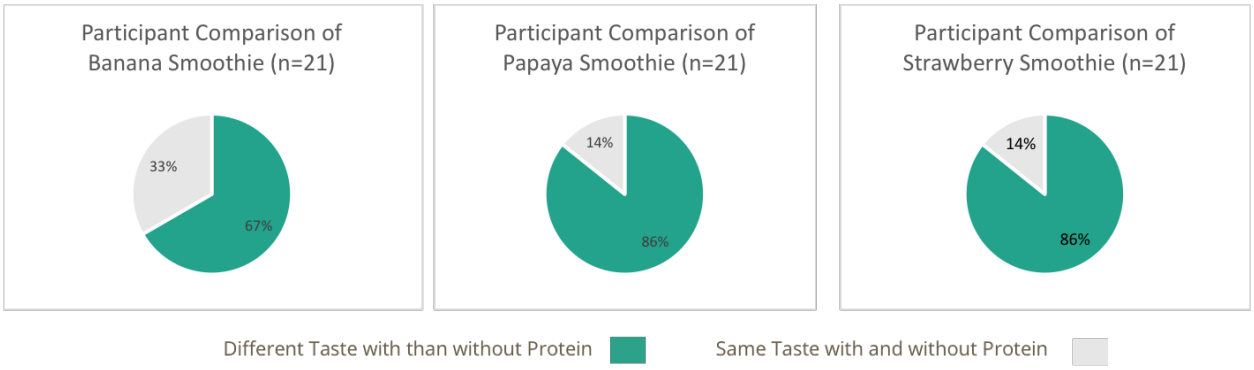
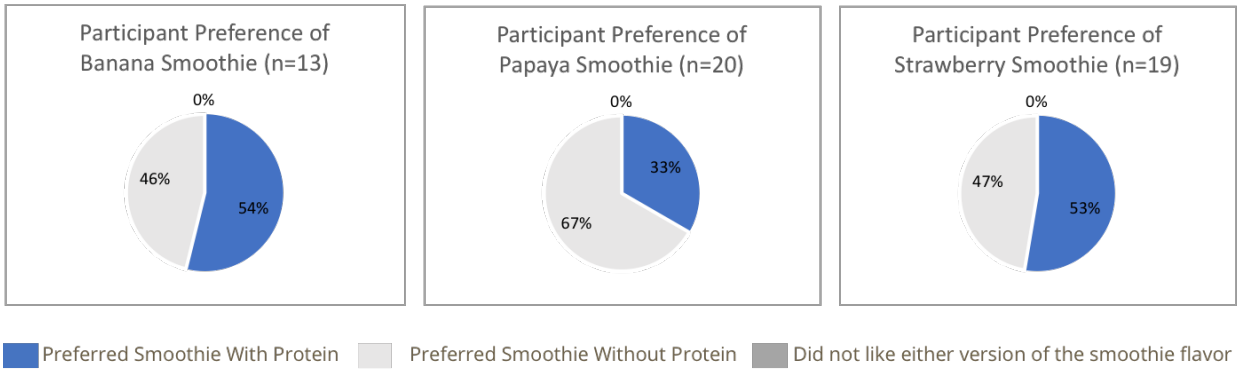


Figure 14. ***Participant comparison (above) and preference (below) of banana, papaya, and strawberry smoothie***



For each sensory panel, the relationship between placement of sample on tray, order tasted of samples, and preference determined was noted in order to determine potential sources of bias and verify the efficacy of the randomization and testing protocol utilized to eliminate such influencing variables on the study. In the following three graphics, the correlation between order tried and preference is examined for each liquid vehicle taste test. The overall data indicates an approximately even split between preference for the first and preference for the second tried, suggesting no bias is present based on order tried, but, interestingly, the breakdown for individual flavors is sometimes much more skewed. For instance, as seen in Figure 15, 76% of participants preferred the first sample they tried over the second. In the overall order versus preference of smoothies, though, this is balanced by the much higher percentages of participants who preferred the second sample over the first for the other two smoothie flavors. Although this

is a notable observation, it can likely be attributed to the smaller data sets of the individual flavors, as there is no factor that should cause differential biases based on order tasted present in different liquid vehicle flavors but not overall.

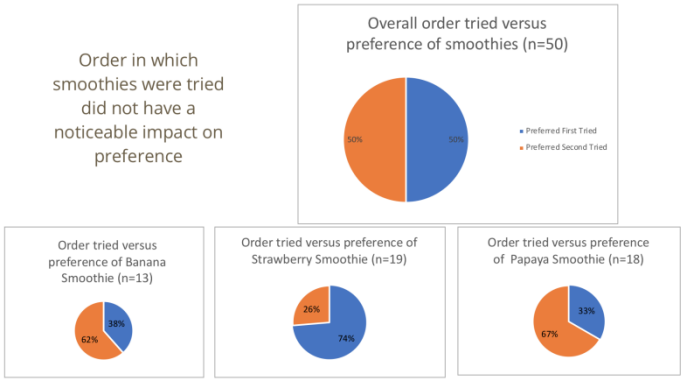
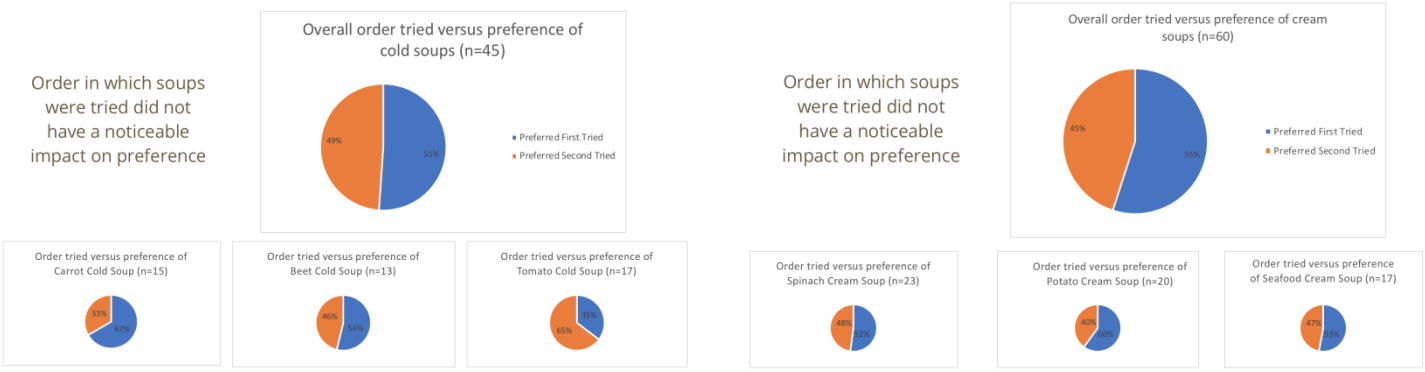


Figure 15. ***Order tried versus preference for each liquid vehicle overall and its individual flavors***



Altogether, the compiled 2017/2018 data indicates that creamy soups have the highest potential to serve as a vehicle for protein supplementation for Guatemalan women of the tested liquid dishes. Although 6-gram whey protein supplementation does create a noticeable difference when added to the liquid vehicle, it generally does not have a negative impact on the palatability of the soup, often even improving its perceived quality. Of the tested flavors across both years, chicken creamy soup appears to have a big comparative advantage for potential success as a

vehicle for supplementation because the highest proportion of participants thought it was enhanced by the addition of protein, and it was among the most commonly reported flavors of consumption in the survey. One benefit, though, of creamy soup supplementation is that it has a high potential to reach a larger audience than other potential vehicles because it offers many flavors, several of which have already been demonstrated to be flavorally improved by the addition of whey protein. Thus women would have a variety of options within their home to prepare the soup and maintain a variety of flavors in the diet.

Milk-based smoothies rank second for potential success as a liquid vehicle for protein supplementation. They fail to meet the same criteria of existing consumption as creamy soups do because, while fruit smoothies do frequent the Guatemalan diet, the survey of Guatemalan women indicates that smoothies are commonly prepared with water rather than milk, barring proper supplementation with the creamy textured whey protein supplement. Although this appears an easy adaptation— swapping milk for water in smoothie preparation— many factors such as cost and access to milk would likely inhibit this solution. In light of this fact, milk-based smoothies are a weaker candidate for supplementation, despite the generally positive participants' reflection on milk-based smoothie taste and palatability with protein.

Lastly, both the study and sensory panel indicate very limited feasibility of cold soups as a vehicle for protein supplementation. Not only are they not part of the typical Guatemalan diet reported, the survey suggests that the Guatemalan population has very little knowledge about this liquid vehicle in general. Thus, it would be difficult to encourage use of this vehicle for whey protein supplement because there is a large implementation barrier, and it fails to conform to existing culture.

The procedure used was effective and thus would be recommended for future research on this topic. One minor change to the survey used for both background information and the sensory panel is recommended: adding more details and specificity to the questions to gain clarity and a better understanding of the liquid vehicle's potential for successful supplementation in communities. To do this, asking questions specifically targeting this question, such as, in the sensory panel portion: "Would you serve this at home if the materials were available to you", and, in the survey portion: "Which of the following ingredients do you have regular access to at home?" followed by a list of many ingredients, including, but not limited to, those used in conducting the sensory panel. Further research could enhance this study with the further exploration of other liquid vehicles, such as the commonly consumed rice milk drink Horchata, and study among more geographically diverse groups (i.e. conduct sensory panels and surveys amidst communities in several different regions of Guatemala).

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Appendix

PROYECTO LICUADOS Y SOPAS FRIAS
Antigua, Nuestros Ahijados
25/06/2018

Entrevistadora: Mónica (licuados), Tere (licuados), Liza (sopas frías)
Código: LS_____
Nombre participante: _____
Edad: _____ años

Muestra	Código	Orden en que se probaron las muestras (de 1 a 6)	A su paladar Ud. cree que estas muestras:		Si responde "son diferentes": ¿De estas 2 muestras cual le gusto más?	¿Porque le gusto esa muestra?	Si responde "son iguales": ¿Le gustaron o no esas muestras y porque? Sí ☐ No ☐
			Son iguales	Son diferentes			
Banano	340						
	356						
Fresa	450						
	466						
Papaya	560						
	576						

Licuado de Papaya

Rinde: 1 litro (16 porciones de ¼ tz)

Ingredientes:

2 tazas de Papaya picada

2 tazas de Líquido: Agua y Leche

5 cucharadas soperas de azúcar

4 sobres de proteína

Preparación:

- Agregar la fruta en la licuadora, el azúcar y el líquido.
- Licuar hasta que la fruta se haya homogenizado.
- Servir inmediatamente.

Observaciones:

La proteína, agregarla antes del líquido.

Licuado de Fresa

Rinde 1 litro (16 porciones de ¼ tz)

Ingredientes:

2 tazas de fresa picada

2 tazas de Líquido: Agua y Leche

6 cucharadas soperas de azúcar

Preparación:

- Agregar la fruta en la licuadora, el azúcar y el líquido.
- Licuar hasta que la fruta se haya homogenizado.
- Servir inmediatamente.

Observaciones:

La proteína, agregarla antes del líquido.

Licuado de Banano

Rinde 1 litro (16 porciones de ¼ tz)

Ingredientes:

2 tazas de banano picado

¼ cucharadita de canela molida

2 tazas de Líquido: Agua y Leche

6 cucharadas soperas de azúcar

Preparación:

- Agregar la fruta en la licuadora, canela, azúcar y el líquido.
- Licuar hasta que la fruta se haya homogenizado.
- Servir inmediatamente.

Observaciones:

La proteína, agregarla antes del líquido.

BASE DE CALDO DE POLLO

1. 1 cuadril de pollo crudo partido en trozos pequeños
2. 2 zanahoria partida en trozos
3. 1 puerro partido en trozos
4. 2 papas medianas
5. 4 tazas de agua
6. ½ manojo de cilantro

Coloque en una olla con tapadera todos los ingredientes y póngalos a cocer por una hora.

SOPA DE REMOLACHA

1. 2 tazas de caldo de pollo
2. 2 tazas de agua hervida o agua salvavidas
3. 2 remolachas cocidas
4. 2 papas cocidas
5. 1 trozo de puerro cocido
6. Unos tallos y hojas de cilantro
7. 1 cucharadita de sal o sazón al gusto

Coloque en la licuadora las 2 tazas de caldo de pollo junto con los vegetales que indica la receta de sopa de remolacha y licue hasta que no queden grumos, luego coloque en una olla y agregue los ingredientes licuados con las 2 tazas de agua, sazone al gusto y caliente si desea servir la sopa caliente, si la quiere servir fría, coloque en la refrigeradora por un par de horas antes de servirla.

SOPA DE ZANAHORIA

1. 2 tazas de caldo de pollo
2. 2 tazas de agua hervida o agua salvavidas
3. 2 zanahorias cocidas
4. 1 papa cocida
5. 1 trozo de puerro cocido
6. Unos tallos y hojas de cilantro
7. 1 cucharadita de sal o sazón al gusto

Coloque en la licuadora las 2 tazas de caldo de pollo junto con los vegetales que indica la receta de sopa de zanahoria y licue hasta que no queden grumos, luego coloque en una olla y agregue los ingredientes licuados con las 2 tazas de agua, sazone al gusto y caliente si desea servir la sopa caliente, si la quiere servir fría, coloque en la refrigeradora por un par de horas antes de servirla.

SOPA DE TOMATE

1. 2 tazas de caldo de pollo
2. 2 tazas de agua hervida o agua salvavidas
3. 4 tomates cocidos
4. ½ cebolla cruda
5. 2 dientes de ajo picados
6. Unos tallos y hojas de cilantro fresco
7. 1 cucharadita de sal o sazón al gusto

Coloque en la licuadora las 2 tazas de caldo de pollo junto con los vegetales que indica la receta de sopa de tomate y licue hasta que no queden grumos, luego coloque en una olla y agregue los ingredientes licuados con las 2 tazas de agua, sazone al gusto y caliente si desea servir la sopa caliente, si la quiere servir fría, coloque en la refrigeradora por un par de horas antes de servirla.

CUESTIONARIO

PREAMBULO: Estamos interesados en el consumo de sopas ya que estos alimentos pueden proveer a usted y a su familia una serie de nutrientes.

1. **Una "sopa cremosa" es una sopa con leche o crema añadida para darle una consistencia suave. ¿Alguna vez ha consumido una "sopa cremosa"?**

   Sí [ ] No [ ]

2. **¿Prepara Ud. las sopas cremosas de sobre o de ingredientes naturales?**

   De sobre [ ] De ingredientes naturales [ ]

3. **¿Qué tan seguido consume en su casa?**

   a. **Sopa de sobre**
      [ ] Nunca, o menos de una vez al mes
      [ ] 1 a 3 veces por mes
      [ ] 1 vez por semana
      [ ] 2 a 3 veces por semana
      [ ] Más de 3 veces por semana

   b. **Sopa natural preparada en casa**
      [ ] Nunca, o menos de una vez al mes
      [ ] 1 a 3 veces por mes
      [ ] 1 vez por semana
      [ ] 2 a 3 veces por semana
      [ ] Más de 3 veces por semana