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Low-Cost Solar Cooler: Addressing Refrigeration Needs In Base of the Pyramid Markets

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November, 2016



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Low-Cost Solar Cooler: Addressing Refrigeration Needs In Base of the Pyramid Markets

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Executive Summary

Opportunity ILUMÉXICO sells solar home systems and offers after-sale services to rural Mexican communities, providing over 30,000 customers access to light; however, very few of these customers have refrigeration. ILUMÉXICO has the opportunity to address an unmet need by providing low-cost refrigeration in addition to light, thus helping its customers climb the energy ladder.

Research Activity Our team conducted 18 semi-structured interviews with ILUMÉXICO customers in order to obtain feedback on the current solar cooler prototype designed by a team of Santa Clara University engineering students. Additionally, the interviews obtained possible positive impacts a solar cooler can have on customers' lives.

Results All 18 individuals interviewed provided positive feedback on the design of the solar cooler prototype and said, if given the proper circumstances, they would use and buy the product, implying that ILUMÉXICO has a strong market opportunity to sell the solar cooler in Campeche.

Deliverable This report analyzes the collected data and illustrates the need for refrigeration in rural communities through a short story. It describes the potential benefits of selling a solar cooler in rural México, delineates the economic, health, and social impacts this product would have on customers if implemented, and provides suggestions for ILUMÉXICO's next steps to bring the solar cooler to the market.

Recommendations Based on the research conducted, our team recommends that ILUMÉXICO conducts additional research on the user experience of the solar cooler through pilot programs and finds a manufacturer to mass-produce the product in order to conduct the pilot programs. By doing so, ILUMÉXICO will be able to bring this solar cooler to market.

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Part 1

Study Overview

To investigate the opportunity of bringing off-grid cooler technology to rural communities in Mexico, our team conducted 18 semi-structured interviews in two rural communities in Campeche, Mexico. The interviews obtained specific feedback from ILUMÉXICO customers about the current design of a solar cooler prototype. Interviews were segmented into two sections: one about customers' food consumption and storage habits to establish how a solar cooler could positively impact their daily life; and their responses and reactions to a nonfunctional solar cooler model to evaluate how well the current design fits their food storage needs, and what features would improve the technology (refer to Appendix A).

Results

Food Consumption and Storage Habits

From the interviews conducted, we found that on a weekly basis, people travel on average once or twice to a small town (such as Escárcega) to buy food. These trips generally take at least four hours round trip, depending on mode of transportation. When people do not go to these larger town markets, they have access to one or two small convenience stores within their own communities that have supplies, non-perishables, and snacks to satisfy some of the community's food needs. People will usually go to their local community store daily to buy dry goods such as beans and rice. While this more convenient option exists, these stores lack the fresh fruits,

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vegetables, and other healthier options necessary for adequate nutrition, in large part because they are also limited by a lack of refrigeration.

When asked about the duration of food, 91% of respondents answered that food lasts no more than two days (refer to Appendix D, Figure 3). They generally cook only what they will eat for a specific meal in order to prevent food waste and to save money. In the event there are leftovers, they store it in a pot and 64% said they reheat the food for the next meal (refer to Appendix D, Figure 2). Unfortunately, this practice can expose these families to a higher risk of food-borne illnesses due to food spoilage.

Overall, people have limited variation in their diets and will choose the most economic items to sustain themselves. People most commonly consume starches such as beans, rice, pasta, corn, and tortillas (refer to Appendix D, Figure 1). Of those interviewed, 91% stated that they regularly buy beans, since they are usually available in the local convenience stores within their communities as mentioned above. This is partly an economic decision because the beans are inexpensive, filling, and can be stored without refrigeration for 3 to 4 days. Seventy-three percent of the individuals interviewed said they most often eat chicken, turkey, or eggs for protein since many of them raise either chickens or turkeys themselves.

The most common method of food storage found was leaving cooked food in the pot in which it was prepared. However, this does not keep food fresh. Without effective food storage, people apparently buy less meat, fruits, or vegetables. In particular meat, especially frozen meat, is something 64% of participants would like to buy but currently cannot (refer to Appendix D, Figure 4). Since refrigerated food storage is unavailable, and because Campeche regularly experiences high temperatures and humidity, food spoils quite quickly, and this is especially true for fresh produce and meats. Therefore, food choices are made in part based on the limited food storage methods that are available to them. The lack of refrigerated food storage options that

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would preserve fresh foods leads to individuals to choose foods that often cannot fulfill all of their nutritional needs.

Solar Cooler Feedback

The second segment of the interview protocol consisted of customers' perceptions of a solar cooler model. After being introduced to the nonfunctional cooler model and its anticipated product attributes, 100% of the customers expressed interest in the product. They asked many practical questions about the product and its anticipated attributes. For instance, 100% of the individuals inquired about the price of the cooler because they were interested in whether they had the means to pay for this product and how they would be able to do so. Forty-five percent of individuals interviewed also asked which panel size the cooler is compatible with, indicating they wanted to understand the feasibility of owning this product. In 73% of the interviews conducted, individuals said they would like it if the cooler were larger in size, in order to meet the family's food storage needs. However, if the actual cooler technology is the same size as this model, those interviewed stated that they would still be content with the size. All individuals interviewed said they would use the cooler and could imagine how it could change their lives because they would be able to buy a wider variety of food, particularly red and frozen meats, and be able to store food for an extra day. In 33% of the interviews conducted in the community of Tabasco, people mentioned how they would use ice to preserve food. According to several individuals interviewed, a bag of ice costs five pesos and about five bags would be needed to adequately conserve food, which amounts to twenty pesos. However, due to the heat, the ice bags do not last long. One woman said that there have been occasions when the ice finally arrived at the house, it was already half melted. Because of this, she said that she does not usually buy ice and will only do so once in awhile. Since using ice is not the most economic way to preserve food, people try to avoid buying ice or buying food that would require the use of ice.

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When asked if they would buy the solar cooler, 91% of the interviewed individuals responded that they would buy the cooler because they like the concept of having a cooler to use and could imagine how such a product could change their food habits and methods of food preservation. However, all those interviewed asked for the price because they wanted to calculate the potential impact this product would have on their finances. Some even asked more practical questions about which panel size the cooler would work with and what the monthly payment plan would be. These responses suggest that even though customers are interested in buying and using the solar cooler, they are price sensitive.

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Part 2

Journeying to the Town Market

This fictional short story illustrates the current situation that individuals throughout rural Mexico face on a regular basis. It draws together and highlights the words and experiences of people that we interviewed to present the social need for and opportunities to introduce a solar cooler.

The first rays of dawn shine on El Encanto, a small rural Mexican community. The sun peeks through the cracks between the wooden panel walls of the house, waking Maria and her husband. Maria sits up in bed, looking at her three children, all still fast asleep in the other bed they built. She rolls off the bed and prepares a breakfast, boiled eggs and tortillas, for her family. As she is boiling the eggs, she notices how low they are on food. Sighing, she thinks to herself, “I have to go to the market again—we only have enough food to last through today.” She had just been to the market in town two days ago.

Once her children have gone to school and her husband to work, Maria makes her way to the market. The nearest town is an hour’s walk from her community. As she begins her trek, Maria lifts her face upwards. It’s a cloudless morning and it’s already 70 degrees with humidity, meaning it will be an especially hot day. “I’ll have to hurry before the sun gets too strong,” Maria thinks as she lowers her head, gazing at the familiar path to the town.

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Maria finally arrives at the market, huffing and puffing, sweat dripping down her forehead. A mere hour has passed but it has already gotten much hotter and more humid. Heading straight for the market she normally goes to, Maria is determined to grab her regular food items and leave. She walks briskly through the muggy store. The damp air clings to her already sweaty skin, until suddenly, the warm, dense air turns cool and crisp. Unable to resist this refreshing sensation, Maria pauses in her stride and turns her body towards the source of her relief: a refrigerator. Inside the refrigerators, she sees cold drinks, reminding Maria of her parched throat and wish she could have even just a taste of the chilled, sugary drinks. Her eyes linger on the contents of the refrigerator. Her family would love to have these at the end of a hot day. She was tempted to buy some. It would be wonderful to have them.

Pulling her eyes away, she resumes her mission. She knows her family can't afford such luxuries; besides, they won't be cold by the time she gets back home anyway. She buys all the food that she can afford and that will keep in this heat. She pays and begins her return trip.

While leaving the city, she passes a man who is selling chilled juices. Once again, she wishes she could buy some for her family. "It'd be such a treat," she thinks as she wipes the sweat off her brow. She readjusts her bags of food in her hands and continues walking home. Along her journey, her mind continually wanders back to the cool sensation that emanated from the refrigerator. "If only we could have something cold when it's so hot. Even if just a little. It'd be nice to have a cooler, too. We could buy more food like meats and store it for longer. I wouldn't have to go to the store so often. My family could have a nice cool drink when they get home. It would be so nice. It would make life a little more enjoyable."

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Need and Opportunity

In 1834, the advent of the first functional vapor-compression refrigerator radically altered our approach to food preservation and our dietary habits. The refrigerator extended the shelf life of various food items, especially meats and produce, as the cold air slowed the metabolic growth rate of bacteria. It reduced food spoilage as people had more time to consume the foods they purchased. It preserved not only the quality of food, but also the flavor of food, allowing people to enjoy their leftovers later on. Because of refrigeration, people have been able to savor life to a larger and deeper extent. However, nearly two centuries later, this terrific technology has still not reached everyone. Refrigeration has been known to be expensive and inaccessible in developing countries, particularly since it is directly linked to electrification. Twenty-one percent of the world population does not have access to electricity and therefore does not have access to refrigeration [1]. In fact there are over 1.3 billion people without access to consistent or grid-based electricity [2].

This lack of refrigeration has multiple negative consequences on the quality of life, chief among them, nutrition. The World Health Organization's study on diet and nutrition from 2010, as reported by Time Magazine, stated that 351,000 people die annually worldwide of food poisoning, a sickness that is often connected to improper food storage [3]. The World Food Programme reports that one in nine people do not have adequate amounts of food to be able to lead healthy and active lives [4]. The insufficient quantity of food can be, at least partially, addressed with access to refrigerated food storage. Furthermore, the United Nations estimates post-harvest losses to be at 45% for fruits and vegetables, which results in a total loss of 4 billion USD in Africa annually [5],[6]. Other studies have shown that food spoilage is a major cause of hepatocellular carcinomas [7].

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Women and children especially bear the brunt of malnourishment. Since women are traditionally viewed as the caretakers of the house, they are responsible for the household's dietary habits. Women's trips to the market can take up the majority of the day, resulting in lost economic productivity. Furthermore, because they are limited in the variety of food they can buy, women can only afford to cook carbohydrate heavy meals, which consequently affects children's physical and cognitive development, as they do not have enough energy to grow. Over half of children under the age of five experience stunted growth in developing nations as a result of malnourishment [8]. Children are also more susceptible to potentially fatal illnesses such as diarrhea [9]. Thus, the lack of refrigeration, and by extension malnourishment, causes larger health care expenses as families must spend their limited funds and take time off of work or school to recover from their illnesses.

The lack of refrigeration can also have negative economic consequences. Many people in poverty spend the majority of their monthly income on food. In Mexico, those who earn \$1 per day and live in rural areas, allocate approximately 62% of their monthly income to food [10]. However, the foods that they buy are cheap and items that will stave off feelings of hunger rather than provide good nutrition. For instance, people will spend more on rice than on produce or meat since rice can be preserved for longer, comes in larger portions, is cheaper, and is more filling. When faced with food insecurity and economic stress, poor families reduce their dietary diversity so that they can continue to eat without straining their finances [11].

While they are able to meet the minimum caloric need for their bodies to simply function, the imbalanced diets of individuals in poverty can lead to malnourishment, meaning they are eating adequate amounts of foods, but are not acquiring enough nutrients for the body to maintain itself [12]. Prolonged malnourishment has adverse effects not only on the body itself, but also on how the person is able to function

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throughout the day. Without the adequate amounts of protein and glucose gleaned from meats and produce, the body is rendered unable to synthesize enough energy for a person to use [13]. Thus, an impoverished individual who has a job in manual labor will lack sufficient energy to perform, which leads to less productivity and less income. This creates a vicious cycle in which individuals living in poverty do not eat properly because they lack adequate funds to buy food and, in their diminished state, cannot earn more money to buy larger amounts of food [14]. This is also often referred to as a poverty trap.

In recent years developing nations, particularly Latin American countries, have made the great strides in making affordable refrigeration technologies available, yet many last mile, off-grid communities cannot access them [15]. The urban and peri-urban middle class has been the primary beneficiary of this progress because they have reliable access to electricity and adequate funds to support the energy needs of conventional refrigeration. The limited reach of electrification is the greatest obstacle to bringing refrigeration technologies to rural communities, and thus alternative strategies are required. With a solar cooler product, ILUMÉXICO could have the opportunity to tap into a market worth over three million dollars and to expand its impact to address economic and health issues that the social enterprise could not previously address with only solar home systems.

Furthermore, the solar cooler presents the opportunity for ILUMÉXICO to bring economic and public health benefits to the communities it serves. Proper refrigeration would enhance the health of people in poverty by improving the diet and nutrition of ILUMÉXICO's customers. A solar cooler would allow people to store food for a longer period of time, which could decrease malnutrition and diminish its effects. By owning a solar cooler, households would consume fresher, more nutritious foods, providing them with more energy to perform their daily functions. Having access to refrigeration technology could also decrease the stunted growth of children since they would have

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access to more sustenance that would give their body the proper nutrients it needs to develop. Improved food storage would also entail fewer trips to the market, meaning that households, and women in particular, would save money and time, which could be reallocated to other productive activities such as working longer hours at their job. Also, as a result of fewer illnesses, people would spend less money seeking medical treatment and less time recovering from food-related illnesses. Mothers especially would benefit from this because instead of spending time taking care of their sick children, they can spend their time on other constructive activities. It could also plausibly decrease illnesses rooted in malnutrition while increasing income since members of the household would save money on illness related costs and perform better in their jobs and at school. The opportunity of selling refrigeration technology in rural off-grid communities presents ILUMÉXICO with the opportunity to increase income and productivity, in addition to addressing health issues. A similar company in Morocco has seized this opportunity, as explained in the following section.

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Evaptainers

Originally a class project at the Massachusetts Institute of Technology, the company Evaptainers aims to provide affordable refrigeration solutions to address the challenges of transporting produce in developing Moroccan markets [16]. The company created and developed Evaptainers, electricity free, low-cost, mobile refrigeration units that utilize evaporative cooling rather than vapor compression refrigeration like traditional refrigerators. Evaporative cooling products have been proven to be effective for agricultural use since they extend the shelf life of most produce from two days to two weeks by cooling the unit up to 35°C from the ambient temperature with low relative humidity (evaporative cooling is significantly less effective in environments with high relative humidity) [17]. This would reduce food spoilage rates immensely. Evaptainers are able to function for two days using only one liter of water [18]. Made from a soft rubberized tub and a semi-permeable fabric, they are designed to be durable, lightweight, collapsible, and highly mobile [19]. Production costs have been at \$15 USD with a sales price of \$25 USD, making it more affordable for low-income consumers [20]. Currently in the final development phase of their pilot program, the company intends to test the latest prototype of Evaptainers with small, rural farmers in Morocco [21].



Photo Credit: Evaptainers

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Conclusion/Next Steps

The data collected in these interviews indicates that there is a viable market for the solar cooler, and ILUMÉXICO could sell this technology. Individuals expressed both a need for and desire to purchase this low-cost refrigeration technology. Despite the positive feedback received in the study, it is important to acknowledge its shortcomings. For instance, this study was constrained to a small sample size of interviewees, and there was an over-representation of females in the study group, relative to males. Our team recommends that ILUMÉXICO conduct additional research to yield the best market results and to move this project forward.

- First, ILUMÉXICO should look for possible manufacturers and calculate a best-case margin cost for the solar cooler, including transportation and taxes, in order to accurately give potential customers a price for the solar cooler.
- Second, now that potential customers have seen the prototype, it would be worthwhile to conduct a user experience pilot study, during which a handful of customers will have a solar cooler in their homes for a month or two and would then report back if they noticed any positive or negative impacts, if they liked the model, if they would buy it, and if they would recommend others to buy it.

Taken together these steps would catalyze this project forward to get the solar cooler on the product line of ILUMÉXICO.

As illustrated through the short story and data, this solar cooler would further the social development of rural communities and of Mexico. Individuals are restricted in terms of diet and spend a significant amount of time going to and from the market, and this is an inefficient process. The long trips to the markets not only consume a great deal of time, but also mean that any purchased food needs to be able to withstand the heat.

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Because of this and restricted diets, approximately 795 million people in the world are food insecure and suffer from malnutrition. Nearly 3.1 million children under the age of 5 living in developing nations die each year due to malnutrition [22]. This problem could easily be resolved with the availability of low-cost refrigeration. Once individuals have the means to store food, not only will they be able to diversify their diet, but they will also be able to have a healthier diet. They will be able to spend more of their time working and less time traveling to the market. Furthermore, having refrigeration technology could allow for increased incomes in families if they decide to start a business using the solar cooler. Overall, this solar cooler addresses some of the unmet needs that individuals face in the Base of the Pyramid market.

This solar cooler represents an excellent opportunity for not only ILUMÉXICO to expand its product line, but also for potential investors to make a substantial investment that could potentially catalyze development in rural Mexican communities and positively impact the lives of individuals as described by potential customers during interviews.

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Appendices

Appendix A: Research and Study

In 2014, two Global Social Benefit Fellows, Alex Cabral and Kiara Machuca, after conducting their research, found a need for refrigeration in rural communities, particularly among housewives, storeowners, and mobile and fresh food merchants. A year later, Kaci McCartan, a student from Santa Clara University, interviewed 8 individuals in rural off-grid Mexican communities to gain their input on the implementation of a solar-powered backpack cooler. She found that while people were not interested in a backpack cooler, they were still interested in using a solar cooler. As a result of Kaci McCartan's research, the Miller Center, ILUMÉXICO, and the Santa Clara University Frugal Innovation Lab collaborated on a project in which a group of Santa Clara University engineers developed a solar cooler prototype.

Over the course of seven weeks Madeline Nguyen and Isabel Miranda (authors of this report) conducted a solar cooler study to gain customer feedback on the current design of a solar cooler prototype. The objective was to gain customer perspective on the usability and market viability of this product. Using a series of questions concerning customers' food consumption and storage habits and reactions to a nonfunctional solar cooler model, we interviewed 18 customers about how a solar cooler could impact their daily life, how the current design fits their needs, and how the technology could be improved.

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Appendix B: Methodology

The 18 semi-structured interviews were conducted two rural communities in Campeche, Mexico: Tabasco and El Encanto. All interviews were recorded in order to fully capture individual's responses. These interviews were later transcribed into a master document and translated from Spanish to English. Each interview lasted between 10-30 minutes. In order to gather qualitative data, these interviews were semi-structured to allow us to adjust to customers' responses as needed. The community engineers took Madeline Nguyen to rural communities that were comprised of ILUMÉXICO customers. From there, the customers directed Madeline Nguyen to other ILUMÉXICO customers in the community. Due to work schedules, women were primarily interviewed. ILUMÉXICO representatives were not present during any of the interviews..

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Appendix C: Interview Questions

1. What foods do you primarily eat?
2. What do you use to store your food?
3. For how long does the food last?
4. What do you do with the food that you cannot store?
5. How many times in a week do you go to the market?
6. What food would you like to buy that you cannot buy right now?
7. What do you think of the cooler? Of its design?
8. Would you use it? How?
9. What would you change?
10. Do you want it to move?
11. Do you like how the door opens, or would it be more comfortable if the door opened from a different side?
12. Do you want it to be...
 1. Taller?
 2. Wider?
 3. Deeper?
13. Do you want to add any other thing to the design?
14. How would this product change your life?
15. Would you be able to buy the food that you want?
16. Would you buy the cooler?
17. How much would you pay for it?
 1. 500MX
 2. 1000
 3. 1500
 4. 3000
 5. 3500

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Appendix D: Data Charts

Food Choices

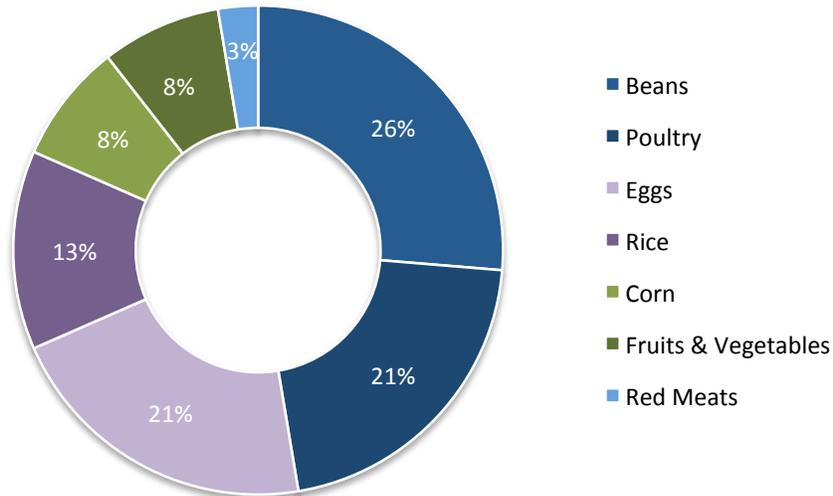


Figure 1: Food Choices. Shows the most commonly purchased food items customers reported.

Food Preservation Methods

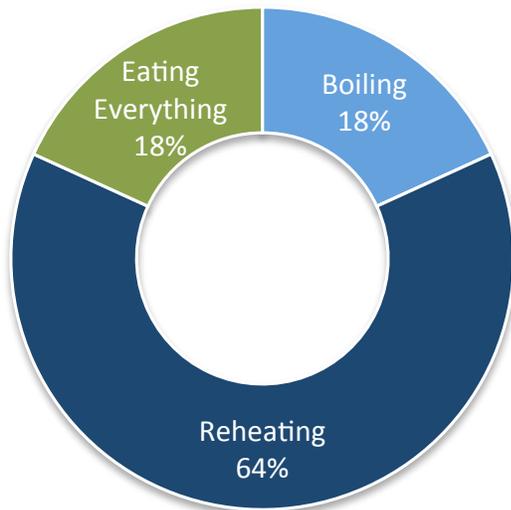


Figure 2: Food Preservation Methods. Shows the most common food preservation methods used by customers.

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Food Duration

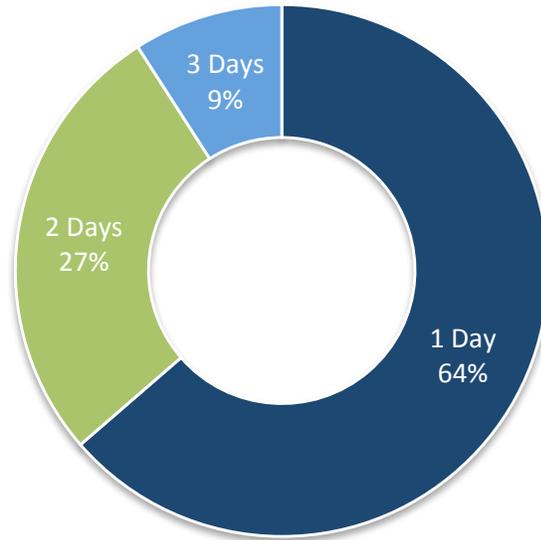


Figure 3: Food Duration. Shows how many days food lasts according to customer responses.

Desired Foods

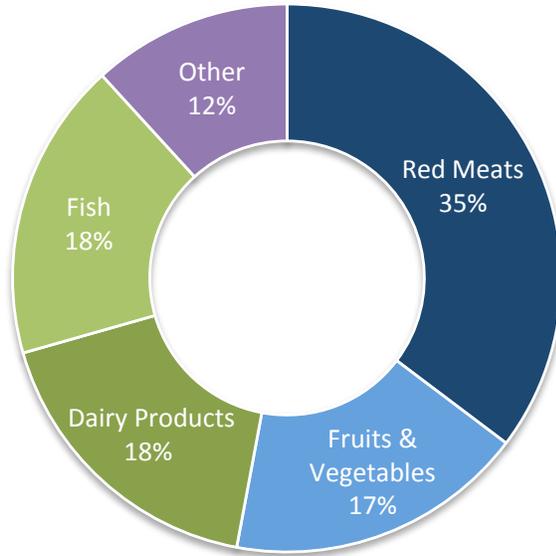


Figure 4: Desired Foods. Show what foods customers would like to buy.

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