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Optimization of Broken Rice Consumption through Understanding the Confluence of Sensory and Economic Preferences

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Optimization of Broken Rice Consumption through Understanding the Confluence of Sensory and Economic Preferences

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Abstract

The authors were perplexed by the seeming dichotomy between the majority 70% of Haitian consumers being chronically food insecure, but still preferring to pay premium international market prices for long-grain rice that constitutes 30% of the calories in this poorest nation in the Western Hemisphere**.** The aim of this study was to determine the optimal percent broken rice in regards to price specifically to Haiti. Optimization between quality and price point is seen as the best rice for the price, and can be found through combining individual preferences with willingness to pay. Broken rice (brokens) garner a significantly discounted price compared to the whole grains, despite offering very similar, if not the same or better, nutritional quality. Through analyzing rice samples with concurrent surveys from 300 Haitians, we were able to determine that brokens have a relatively small effect on consumer preferences in Haiti. This indicted that less strict import standards on broken percentage of rice could benefit the welfare of Haitians in need of discounted food supply. To supplement these findings, a sensory study in the University of Arkansas Sensory Service Center was conducted with the aim of determining brokens' impact on rice consumers both pre-purchase and post-cooking. Broken rice is sold at a significant discount worldwide, and this study aimed at understanding why that discount persists and if the discounts perpetuated by producers are aligned with consumers' willingness to purchase broken rice. Through testing rice-eating consumers' perception of the same rice samples in their raw and cooked forms with percentage broken being the only independent variable (in incremental percentages of 5%, 10%, 20%, 30%, and 40%), the results showed that the raw rice's appearance with high levels of brokens is disproportionately affecting the broken rice market.

Acknowledgements

I want to earnestly thank my supervisor and thesis director, Dr. Phil Crandall, for believing in me, mentoring me, and encouraging me along the way for the last two years. I have learned a tremendous amount of professional and life skills from him. I also want to thank my two committee members, Dr. Lanier Nalley and Dr. Han-Seok Seo, both of which have given me invaluable guidance to push me towards success. Without their collaborative efforts and dedication, these projects would not have been possible.

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Dedication

This thesis is dedicated to my wonderful wife, Kelly Richardson, whose unyielding love and support has given me the confidence and ability to pursue my dreams.

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Chapter 1: Literature Review and Introduction

1. INTRODUCTION

1.1 Global Rice Use and Trade

Rice (Oryza sativa L.) is considered by many international development experts to be the most important food crop in the world (Buggenhout et al, 2013), responsible for supplying the basic caloric needs for over half of the global population. Global rice production for the 2019/2020 crop totaled almost 500 million metric tons. (Shahbandeh, 2019). Although the United States produces less than 2% of the world's rice, the U.S. rice production accounts for over 10% of the volume of globally traded rice (USDA, 2020). In 2019, the United States produced roughly 9.3 million metric tons (205 million cwt[1]), with Arkansas producing almost half of that at roughly 4.3 million metric tons (95.1 million cwt) (USDA, 2020). One of Arkansas's top producing companies is Riceland Foods, based in Stuttgart, AR. Riceland exports much of their rice, with their two top exporting nations being Mexico and Haiti. In 2018/2019, Mexico imported the most rice from America, at over 823,000 tons, while Haiti imported the second most, at over 442,000 tons. This is considerably higher than the U.S. exports to any other nation, with the next two highest exports to Japan and Canada at 281,000 tons and 252,000 tons, respectively (USDA, 2020). Riceland, among many other companies, has many different types of rice for the many different consumer preferences for customers all over the world. They specialize in U.S. long grain rice, both parboiled and non-parboiled, although

[1] Cwt is abbreviated "hundredweight" or 100 pounds, which is the standard unit of measurement for rice in North America

they produce other types of rice such as medium grain rice, brown rice, rice bran oil, soy products, and ready-to make packages of rice dishes under "Rice 'N Easy" label.

1.2 Sensory Evaluation of Rice

Rice preferences vary based on flavor, aroma, texture, functionality, and appearance. In addition, social and economic factors such as brand value, price, and place of origin all play a role in consumers' preferences in rice (Kim et al. 2017). Although some eat rice as a side dish and prepare it simply with water and salt, others want or need to eat it as a main dish, so they are inclined to flavor it with other aromatics, vegetables, and sauces. In addition, the cooking methods of rice vary greatly depending on preferences and type of rice that is being cooked. Optimal water to rice ratios (W/R) vary greatly based on previous research – anywhere from 0.8:1 to 2.5:1 (Srisawas and Jindal, 2007).

Because of rice's generally bland flavor, the texture attributes of hardness to stickiness ratio have been found to be a strong indicator of overall acceptability (Srisawas and Jindal, 2007), not to say that other factors such as flavor, aroma, and appearance do not play an important role. These characteristics can be found analytically or through sensory studies. Stickiness is largely determined by the rice's proportion of amylose to amylopectin (Crowhurst and Creed, 2001). This has a significant effect on the texture and physiochemical properties. Amylose and amylopectin are the two different types of starch, with amylopectin producing a much stickier starch and amylose producing a more waxy starch. Chemically, amylose is a straight chain polymer whereas amylopectin is a branched chain polymer, meaning that amylopectin is a much larger, more complex molecule. Amylopectin is also much more soluble in water than amylose, and it forms a gel when heated past its gelation point in water (Miles et al, 1985). This means that rice with high amylose content is generally less sticky.

Hardness of the rice can be more difficult to quantify, with tests ranging in methods from puncturing, compression, and extrusion (Perez et. al. 1993). Hardness is often a factor of the amount of water used to cook the rice (W/R ratio) and the cooking time. Optimal cooking time can simply be found through the Ranghino test by removing rice that is being cooked in 60 second intervals until the rice has no white, ungelatinized cores remaining (Juliano et al. 1981), but since then there have been more technical methods of measuring the cooking quality of rice. FT-NIR spectroscopy is an example of relatively recent technology that has been found to accurately (and quickly) measure how rice changes during hydration and therefore how to evaluate the optimal cooking time of rice (Sinelli et al. 2006), but for the purpose of this study, the Ranghino test is accurate and feasible. Longer cooking times generally lead to softer rice. However, the shape of the rice and the physiochemical components of the rice can also play a factor in the determination of the hardness of the cooked rice (Bhat and Riar, 2017). For instance, the higher the amylose content in the rice, the harder the cooked rice, as a result of less swelling of the starch in gelation (Asghar et al, 2012). This is why the optimal W/R increases with increasing amylose content of raw rice (Meullenet et al, 2000).

According to Cowhurst and Creed (2001), overall acceptability of cooked rice depended primarily on the W/R ratio that accounted for 50% of the correlated variation, but they also found that the method of cooking rice has a significant effect on the end-product of the cooked rice through sensory paneling of various samples of rice of different cultivars cooked in different processes. The wide range of 0.8 – 2.5 W/R (Srisawas and Jindal, 2007) is an immense range for such an important factor in rice cooking. This is largely because different cultivars of rice require different cooking procedures to create optimal rice texture. Cooking procedure has a significant impact on many factors of rice such as texture, color, and moisture content (Syafutri

et al, 2016). Rice can be prepared by steaming, cooking with an exact amount of water, or cooking with an excess of water, and by cooking in a rice cooker or on the stovetop. Before cooking, rice is often rinsed with water to remove excess starch on the outside of the rice kernel as well as any foreign material such as dirt. This is believed to not only reduce the stickiness between the rice kernels, but also to ensure that their rice is clean. Interestingly, it has also been shown that despite this preservative consumer practice of rinsing raw rice, there is no correlation between foreign materials adhering to the surface of raw rice and the end texture of the cooked rice (Li et al, 2019). Methods of cooking, preparation, and storage/transportation conditions of rice differs widely in different cultures as well as for different types of rice. Ultimately, the end use of the rice should be kept in mind when deciding between variety of rice and cooking method, as these factors greatly change how to reach optimally cooked rice.

1.3 Rice Preferences in Regards to Culture

Studies conducted by international researchers have found that individual consumers' preferences often change in regards to rice among countries, or even between regions in the same country (Champagne et al., 2011). Beyond that, peoples' preferences and the price consumers are willing to pay for rice also depends on their demographic and socioeconomic background. These behavioral economic preferences reflect peoples' priorities both intrinsically and extrinsically (Espejel et al. 2007). Rice's intrinsic values would be its taste, color, texture, length, chalk, and percentage brokens, while extrinsic values would be origin, money on hand, brand, price, cleanliness, ethics (fair-trade, organic, etc.), and packaging.

More than 90% of the world's rice is grown in Asia, but only a tiny fraction, 7%, of this rice is offered for international trade with the bulk being consumed in each producing country. However, the consumption is actually declining significantly per capita in several Asian countries, such as Japan and Taiwan, as a result of changing lifestyle and taste (Bairagi et al. 2017). This is largely because these countries have become increasingly urbanized. Urbanization has invariably lead to people having more options in selection of foods. This increased level of choice has caused foods that used to be the only option to decrease in consumption as people are naturally inclined to not to eat the same thing for every meal if given the choice (Devine, 2005). Globalization has also caused people to travel more and have access to goods from all over the world, so people are eating a wider variety of food from outside of their local region more often than ever (Inglis and Gimlin, 2009).

Rice attributes	Preference ranking	Bangladesh		India			Indonesia	Cambodia	Philippines	Thailand	Vietnam	SA	SEA	All
		Urban	Rural	East	South	Rural	Urban	Urban	Urban	Urban	Urban			
Taste	0	36.7	60.5	39.4	76.8	42.5	88.2	99.8	78.9	48.4	55.7	52.0	73.2	62.4
	1	23.9	14.4	14.3	7.3	12.3	3.1	0.0	2.1	18.2	10.1	14.5	7.1	10.8
	2	31.0	15.7	33.3	9.4	28.8	2.6	0.0	11.4	29.9	25.9	23.1	14.6	18.9
	3	8.4	9.5	13.0	6.6	16.4	6.1	0.2	7.6	3.5	8.3	10.5	5.1	7.8
Texture	0	64.5	68.8	55.2	23.4	23.6	19.9	9.2	13.8	80.6	55.0	50.5	37.8	44.3
	1	8.6	6.7	12.3	35.6	44.9	43.3	64.2	51.2	2.6	5.7	18.7	31.1	24.8
	2	17.2	17.5	22.3	31.1	17.5	24.8	22.1	24.6	13.6	31.3	21.1	23.7	22.4
	3	9.6	7.0	10.2	9.8	14.0	12.1	4.6	10.4	3.3	8.0	9.7	7.4	8.6
Aroma	0	77.1	57.7	83.5	60.7	36.6	26.5	54.2	46.4	76.6	81.1	65.1	59.2	62.2
	1	5.7	8.2	3.5	5.6	15.1	16.8	5.0	12.1	1.4	1.7	7.0	6.6	6.8
	2	10.1	31.5	6.9	16.4	26.7	37.1	26.0	28.0	18.9	11.6	18.4	23.3	20.8
	3	7.1	2.6	6.1	17.3	21.6	19.6	14.8	13.5	3.0	5.6	9.4	10.8	10.1
Appearance	0	15.3	13.9	9.7	13.6	58.9	28.1	21.3	49.1	6.5	5.9	18.8	19.4	19.1
	1	53.2	65.4	60.0	43.3	16.8	25.8	21.9	23.2	67.8	79.5	51.6	46.9	49.3
	2	19.2	13.9	21.7	31.9	13.0	22.5	31.3	17.6	9.3	10.6	19.9	18.1	19.0
	3	12.3	6.9	8.6	11.2	11.3	23.6	25.6	10.0	16.4	4.0	9.6	15.7	12.6
NB	0	80.0	83.0	79.2	78.7	78.8	95.7	94.8	67.5	70.3	82.8	80.2	83.5	81.8
	1	4.9	1.8	5.9	6.8	5.1	0.9	1.7	9.3	2.6	0.9	4.7	2.5	3.6
	2	10.3	10.6	9.7	7.7	7.9	1.7	1.3	12.8	22.0	10.6	9.4	9.3	9.4
	3	4.7	4.6	5.2	6.8	8.2	1.7	2.3	10.4	5.1	5.7	5.6	4.7	5.2
CC	0	77.3	80.6	85.7	89.2	77.4	72.3	60.6	91.3	78.0	82.8	82.4	76.1	79.3
	1	2.7	3.4	3.7	0.9	5.8	9.9	7.3	2.1	7.5	1.9	3.2	5.7	4.4
	2	11.8	9.5	5.8	2.1	6.2	10.4	18.5	4.8	6.3	8.5	7.2	10.2	8.7
	3	8.1	6.5	4.8	7.7	10.6	7.3	13.5	1.7	8.2	6.8	7.2	8.0	7.6

Notes: 1, 2, and 3 are the first, second, and third most-preferred attributes, respectively; 0 refers to a choice being unranked; NB and CC are nutritional benefits and cooking characteristics, respectively.

Figure 1: Rice Preferences in South and Southeast Asia (Baigari et al. 2017)

In addition, aromatic rice is becoming more popular in some areas of Asia (China and Southeast Asia) largely purchased by consumers who have comparatively higher education and income (Bunyasiri and Sirisupluxana, 2017, Custodio et al. 2016). In these studies, it was also found that women were more likely to prefer aromatic rice and valued aroma higher in general when purchasing rice. Baigari and others (2017) surveyed respondents to rank their preferences of rice with the choices of taste, texture, aroma, appearance, nutritional benefits, and cooking characteristics. They found in a wide reaching survey that preferences varied greatly country to country and rural vs. urban. Figure 1 above illustrates how different peoples' priorities in purchasing rice can vary so greatly between country and region. Research such as this that highlighted how culture shaped preference of foods has proven that it is crucial for companies to create products that can be tailored specifically for a country or region. Almost every country's most-preferred attributes was slightly different, but placing a high value on texture and appearance was common throughout. These are both attributes that broken rice can alter, leading one to believe that percentage broken is an important contributing factor to many people if they believe that the brokens negatively affect the texture or appearance of the rice.

This served as part of the original basis for the sensory portion of the study that we conducted. Through visual tests of uncooked rice with varying levels of brokens and taste tests of rice with varying levels of brokens, we sought to see how great of an impact percentage brokens had on a potential consumer. We altered the percentage broken in 5% increments with the goal to see if there was an increment that significantly deterred people from rating the rice highly in multiple sensory categories or from being willing to purchase the rice. Our study's focus was on people of Caribbean decent as well as people who eat rice at least twice a month. In order to supplement our findings from our consumer surveys in Haiti, we needed information

in regards to Caribbean peoples' willingness to pay for rice of varying brokens to determine the optimal level of brokens to be sold to reach the most Haitians who have less income to spend on food. If we were able to perform a sensory study with solely Haitians we would have done so, but given that we had did not have access to a large enough Haitian population to be adequate, we widened the qualification for the sensory study to be Caribbean. Because of the COVID-19 Pandemic, the population of Caribbean people in Fayetteville, AR was significantly decreased, making it impossible to retain the focus on Caribbean people. Therefore, the study shifted to focusing on rice-eating consumers in general.

1.4 Broken Rice Role to Preferences and Trade

Brokens are defined as rice kernels that are less than 75% of the length of the whole kernel of rice (Standards U.S., 2009). Rice kernels are fractured mainly during the milling process as a result of fissuring, cracking. Increased brokens can be a result of extent of milling, rapid moisture absorption, rapid drying, chalkiness, underdeveloped kernels, and environmental factors such as relative humidity, sudden temperature changes, and insect infestation (Siebenmorgen, Nehus, & Archer, 1998). Brokens can be further classified as "second head milled rice" (second heads), "screenings milled rice" (screenings), or "brewers milled rice" (brewers) (Standards U.S., 2009). Second heads are the largest, screenings the second largest, and brewers the smallest of the brokens. For simplicity, second heads could be thought of as broken that are in between 50%-75% of length of whole kernel, screenings as in between 25% - 50% of whole kernel, and brewers as those that are smaller than 25% of the whole kernel. After the milling process, rice passes through sieves of various sizes that classify the rice according to its length Detailed specifications can be found of the three classes of brokens, as well as all

other considerations when classifying rice grown or sold in the U.S. at USDA.gov "Official US Standards for Rice".

Because brokens' are often perceived "poor" in appearance, they demand a significantly smaller price at retail – in 2020, brokens sold at a 41.89% discount to their whole kernel counterparts (USDA, 2020). Although some brokens are mixed into rice at retail by unscrupulous retailers, brokens are mainly used for pet foods, breweries, skin creams, rice flours (ground brokens), and pastas, breads, and cereals extruded from rice flour (Bruce and Atungulu, 2018). Rice flour is a very popular gluten-free alternative that continues to grow in demand as a wheat replacement.

Grade	Maximum limits of ---												
	Seeds, heat damaged, and paddy kernels (singly or combined)		Red rice and damaged kernels (singly or combined) (percent)	Chalky kernels [1,2]		Broken kernels				Other types [4]		Color requirements [1]	Minimum milling requirements [5]
	Total (Number in 500 grams)	Heat damaged kernels and objectionable seeds (Number in 500 grams)		In long grain rice (percent)	In medium or short grain rice (percent)	Total (percent)	Removed by a 5 plate [3] (percent)	Removed by a 6 plate [3] (percent)	Through a 6 sieve [3] (percent)	Whole kernels (percent)	Whole and broken kernels (percent)		
U.S.No. 1	2	1	0.5	1.0	2.0	4.0	0.04	0.1	0.1	--	1.0	Shall be White or creamy	Well milled
U.S.No. 2	4	2	1.5	2.0	4.0	7.0	0.06	0.2	0.2	--	2.0	May be Slightly gray	Well milled
U.S.No. 3	7	5	2.5	4.0	6.0	15.0	0.1	0.8	0.5	--	3.0	May be Light gray	Reasonably well milled
U.S.No. 4	20	15	4.0	6.0	8.0	25.0	0.4	1.0	0.7	--	5.0	May be Gray or slightly rosy	Reasonably well milled
U.S.No. 5	30	25	56.0	10.0	10.0	35.0	0.7	3.0	1.0	10.0	--	May be Dark gray or rosy	Reasonably well milled
U.S.No. 6	75	75	[6]15.0	15.0	15.0	50.0	1.0	4.0	2.0	10.0	--	May be Dark gray or rosy	Reasonably well milled

U.S. Sample grade:

U.S. Sample grade shall be milled rice of any of these classes which: (a) does not meet the requirements for any of the grades from U.S. No.1 to U.S. No.6, inclusive; (b) contains more than 15.0 percent of moisture; (c) is musty or sour, or heating; (d) has any commercially objectionable foreign odor; (e) contains more than 0.1 percent of foreign material; (f) contains two or more live or dead weevils or other insects, insect webbing, or insect refuse; or (g) is otherwise of distinctly low quality.

[1]For the special grade Parboiled milled rice, see §868.315(c).
[2]For the special grade Glutinous milled rice, see §868.315(e).
[3]Plates should be used for southern production rice; and sieves should be used for western production rice, but any device or method which gives equivalent results may be used.
[4]These limits do not apply to the class Mixed Milled Rice.
[5]For the special grade Undermilled milled rice, see §868.315(d).
[6]Grade U.S. No. 6 shall contain not more than 6.0 percent of damaged kernels.
[56 FR 55979, Oct. 31, 1991]

Figure 2: Grade Requirements for US Rice (USDA, 2009)

Despite brokens being predominantly used in these various secondary ways, they do bring unique characteristics to cooked rice. Saleh and Meullenet (2013) indicated that adjusting the ratio of broken kernels can influence the texture of the cooked rice. Brokens have a higher fragmentation degree than whole kernels, meaning they have larger surface areas due to the area of the kernel that was internal being exposed once broken. This increases the capacity for water absorption, causing decreased hardness. Higher fragmentation degree also increases, under the same gelatinization temperature and cooking duration, the amount of starch to leach out, which creates a more viscous texture. Interestingly, Saleh and Meullenet (2013) also found through sensory evaluations with trained panels that brokens can impact both the flavor and aroma of the cooked rice. In their study, rice was fragmented by various degrees on a weight by weight basis in three prescribed sizes in respect to the whole kernel – 25%, 50%, and 75%. Rice fragmented by 50% increased the intensity of fattiness, sweetness, fruitiness, nuttiness, and toastiness of cooked rice, while rice fragmented by 75% decreased these same parameters. The total amount of volatile compounds also followed a similar trend, with rice fragmented by 50% increasing volatile compounds by 43% and rice fragmented by 75% increasing volatile compounds by 26%, compared to whole-kernel rice.

As of 2018/2019, brokens sold on its own play a small role in U.S. exportation of rice, making up less than 2%, 1.83%, of the total rice exported. These numbers fluctuate significantly year to year. For example, in 2016/2017, brokens accounted for roughly 3.12% of total rice exported (USDA, 2020). Large mills generally generate 10-15% brokens, whereas smaller, generally less modern mills generate as much as 30% brokens (Muthayya et al. 2014). Understanding that brokens offer less return to the rice grower and processor than whole kernel, one can see why this is an economic concern for rice mills worldwide. The less brokens they

generate, the more head rice produced and the higher profit margins become. However, many mills, often in underdeveloped countries, do not have the means or the technology to produce rice with low levels of brokens. These older, lower quality mills are incapable of reaching as high of a head rice yield as a result of less accurate processes of removing the bran and polishing the white kernels or due to poor moisture and temperature control during processing. Factors beyond milling such as quality of rice, storage and transportation conditions, and insects all play sizable roles in the amount of brokens produced as well.

1.5 Importance of Rice in Haiti

These factors are part of the current multitude of problems negatively affecting Haiti's domestic rice production. Rice has become an increasingly important part of Haitians' diets (Cochrane et. al, 2019), but domestic rice production has faltered in the face of this increased demand. The lack of sustained investment in critical infrastructures have limited the long term growth in Haitian locally produced rice over the past 30 years. This can be understood through decreasing yields of domestically produced rice and increased competition of imported rice. Coupled with Haiti's population increasing by roughly 4 million people over the past 25 years and the country being decimated by natural disasters, agricultural growth has been extremely difficult to progress. Haiti's decreasing yields are a result of: lack of maintenance of irrigation, declining quality of land, lack of skilled labor, farm sizes and mills being too small and outdated technologically to be efficient, and farmers having diminishing crucial inputs such as working capital (interest rates for private financing are too high for most to pay), water access, and high quality seeds (Furche, 2019).

Figure 2 Map of Haiti Earthquake in 2010 (Encylcopedia Britannica, 2019)

To make matters worse, weather conditions have severely impacted Haiti's lack of growth, with several tragedies occurring in the last decade. In 2010, a magnitude 7.0 earthquake occurred on January 12th only 25 km away from the capital city, Port-au-Prince, with aftershocks lasting through January 20th (Pallardy, 2020). This caused mass homelessness, severe destruction of infrastructure, roughly 316,000 deaths, and health crises as a result from the lack of sanitation. The effects of this earthquake should not be understated – it is estimated that nearly one-third or three million people were affected by the quake, with over one million left homeless. Haiti lies on the border of the Caribbean and North American tectonic plates, so this earthquake, although the most severe, was not alone in impacting Haiti. Most recently in 2018, a magnitude 5.9 earthquake hit the north end of the island, damaging nearly 16,000 properties and injuring almost 600 people (Almasy, 2018). Because of Haiti's precarious position on the border of two major tectonic plates, experts believe that there is an elevated risk for future earthquakes (Gammon, 2012). And although some prevention and relief efforts have been made, the capital

financing continues to be lacking to fund such projects (as well as proper construction) that would have a lasting impact on aiding Haitians recover and not be as devastated from similar earthquakes (Charles, 2020).

In 2015, a severe drought began in Haiti, hitting the Sud-Est, Nord-Ouest, and Artibonite regions the hardest and lasting through 2017. It caused losses of up to 70% of local agricultural production, worsening the already food-insecure situation for roughly 1 million people in Haiti (ReliefWeb, 2019). With no substantial rain for between 10 and 11 months in 2015, not only were all major crops severely hurt for years to come, but also a significant portion of the livestock that are relied upon for protein and income died of thirst. Because of Haiti's location in the heart of El Nino (an ocean phase that causes increased temperatures), the situation did not improve much through 2017. El Nino is a southern oscillation of air that caused dry, sinking air to hit the Caribbean for several years as well as other large-scale climate shifts in the tropics (NOAA climate.gov, 2020). Crops such as rice were not only decimated during this drought, but the potential for agricultural production is hurt by this as well. Soil deterioration, lack of high quality seeds, lack of capital to invest in land/infrastructure, and a generally lower quality of life caused by droughts all handicap future prospects of crops.

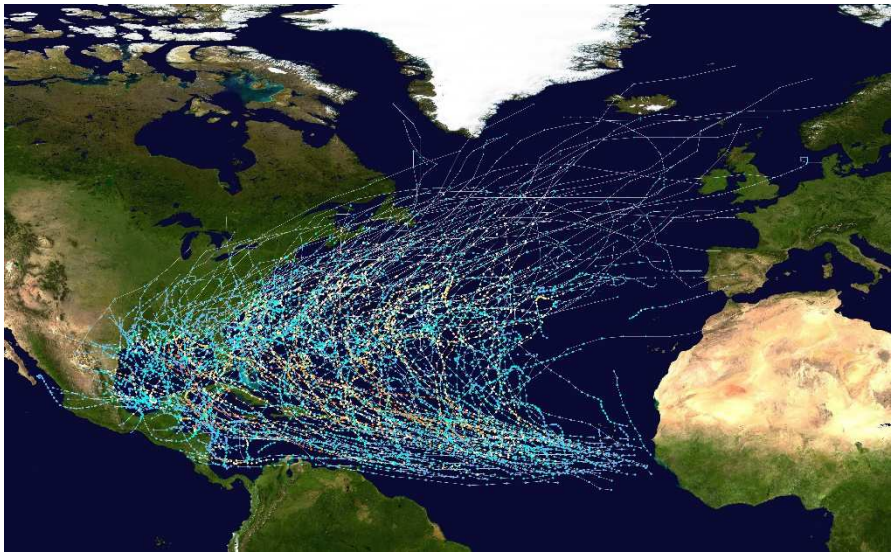

Figure 3 Map of Atlantic Hurricanes (NOAA, 2017):

Then in 2016, Hurricane Matthew caused catastrophic flooding in Haiti, killing roughly 600 people and leaving roughly 35,000 homeless (Stewart, 2016). Again, this was not an isolated event as a result of Haiti's location directly in what is known as "Hurricane Alley" (Goudarzi, 2006). Hurricane Alley is a section of warm water that stretches across the Atlantic Ocean from North Africa's west coast to the Gulf of Mexico. Warm water is the fuel for hurricanes, and the water in Hurricane Alley has actually increased several tenths of a degree Celsius over the 20th century. Although this does not seem like a significant amount, many meteorologists recognize this as a significant contributor to the magnitude and frequency of hurricanes (National Hurricane Center, 2020). Tropical storms and/or hurricanes, since 2002, including Hurricane Wilma, Hurricane Dennis, Tropical Storm Alpha, Tropical Storm Fay, Hurricane Gustav, Hurricane Hanna, Hurricane Ike, and Hurricane Tomas, as well as several torrential rains resulting in flooding, destruction, and thousands more deaths, have all hit Haiti hard in addition to the well-known Hurricane Matthew (National Hurricane Center, 2020). These

are far from isolated events, and seem to be increasing in frequency as temperatures have steadily increased in the region.

After observing these harsh truths concerning the Haitian situation, one can see the underlying causes for what makes agricultural growth in Haiti so difficult. Economic hardships have compounded (and partially resulted from) the island nation being situated on the crux of tectonic plates connecting, "hurricane alley", and El Nino. All three of these things have the power to bring natural disasters to a nation on their own, but having all three of them in one portion of an island is foreboding. It creates an environment that is incapable of supporting a growing population effectively. Therefore, foreign aid is needed - not only in terms of charity and volunteered relief efforts, but also in giving people the ability to buy discounted food and supplies.

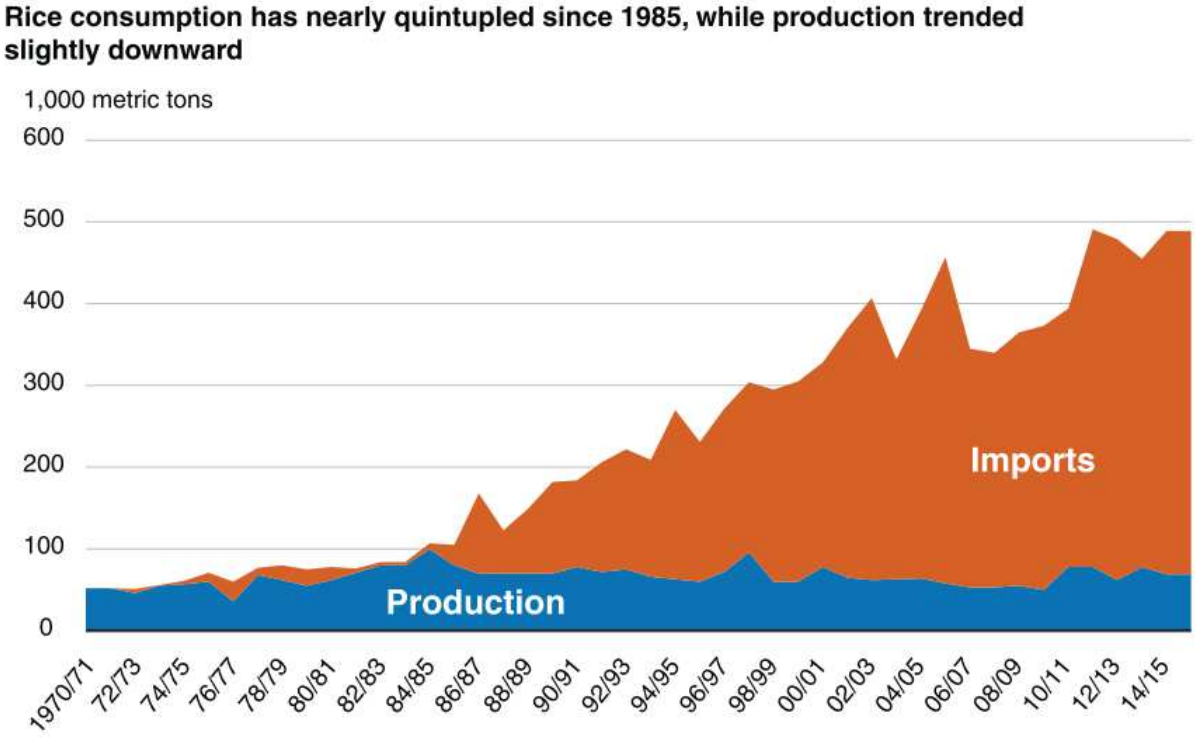

Figure 4 Rice Consumption vs Production (Cochrane et al. 2019)

In 1986, Haiti opened its market to rice imports, but they still had a tax structure in place with a 50% tariff. That year, 7,000 metric tons of rice were imported. Within a year, this had increased to 25,000 metric tons with the U.S. as the sole supplier. By 1994, Haiti was importing 140,000 metric tons of rice from America. In 1995, they reduced the tariff to 3%, and the imports increased again to 207,000 metric tons. Today, 10% of all U.S. rice exports go to Haiti, which is close to 400,000 metric tons of rice and generates roughly $200 million in revenue for the U.S. rice industry (Cochrane et al, 2019). While this is beneficial to American rice producers and many Haitians who rely on inexpensive rice as a staple of their diet, it has made it increasingly difficult for domestic rice farmers in Haiti to compete. As conducted by the United Nations in 2011, rice accounted for nearly 25% of the total calorie consumption of Haitians, but since then this number has increased to close to 30% (FAO, 2018).

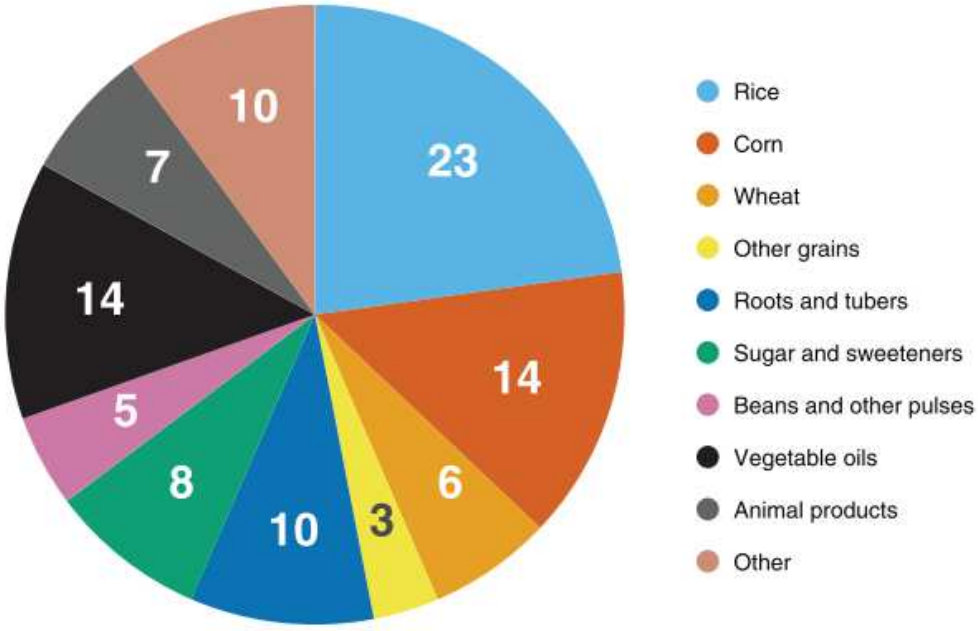

Figure 5: Share of daily calories for Haitians (FAO, 2018)

This is juxtaposed with the fact that Haiti has the lowest Gross Domestic Product per capita in the Western Hemisphere as of 2018 less than $2,000, $1,940, with roughly 70% of its population being food insecure (Cochrane et al, 2019). Roughly 40% of the population is unemployed and roughly 46.8% of the population is undernourished. Although these numbers are painfully high, they have actually decreased over the last 25 years, in large part due to the influx of imported rice among other agricultural imports. These imports have helped cause the GDP to increase by 0.77% from 1980 to 2017, which is not nearly enough to keep up with the high population growth of the country, leading to the GDP per capita to be so low and poverty so high in Haiti.

Figure 8 Haiti GDP per capita compared to Caribbean (Cochrane et al. 2019)

On a humanitarian level, this intense level of poverty deserves international attention. The issue of food insecurity is so extreme that it is necessary it is addressed before other areas of improvement can also be addressed. Although constructing proper buildings to ensure that they do not collapse during a natural disaster is crucial, it is very difficult to perform such laborious work on an empty stomach. Given that rice is a well-rounded, nutritious food that can be produced cost effectively, this is a premium food to be targeted to improve Haitians quality of

life. The difficulty is lies in understanding the most effective way to feed the maximal amount of Haitians while still meeting costs on the supplier side. Figuring out how to effectively offer rice at reduced prices is a worthy goal in attempting to feed more Haitians in need.

As of 2018, rice supplies roughly 30% of the daily caloric intake of the average Haitian (FAO, 2018). Only 17% of this rice supply is domestically grown, with American and Vietnam supplying the majority of this imported amount. Vietnamese imported rice is a distant second to American imported rice, with the U.S. supply roughly 80% of the total rice supply in Haiti (MARNDR, 2016). Two of the most popular U.S. rice brands in Haiti are Tchako and Mega (both 4% broken U.S. long-grain #2). Riceland supplies Tchako S.A. with rice, and the company has recently started marketing a second type of rice, Tigoute, which contains 20% broken and sold at a discount. Haitians have been known to prefer the American rice over the Vietnamese rice, called 10 sou 10, despite the Vietnamese rice being cheaper. The most expensive rice in Haiti is typically the locally produced rice, often called Shella and Shelda, both of which are parboiled rice. Parboiled rice is soaked, steamed, and dried while still in the husk, resulting in a partially boiled rice kernel once removed from the husk (Elbert et al. 2001). Parboiling infuses much of the water soluble nutrients of the bran of the rice, such as the fiber, calcium, potassium, and phosphorus, making it more nutritionally beneficial than white, polished white rice (Amato et al. 2002). In addition, TCS-10 is a popular domestically grown rice that is not parboiled. TCS-10 is slightly more expensive than imported rice, but not as expensive as domestic parboiled rice. This rice is mostly grown in the Artibonite Valley region in Haiti, which accounts for 80% of Haiti's domestic rice production (Furche, 2019).

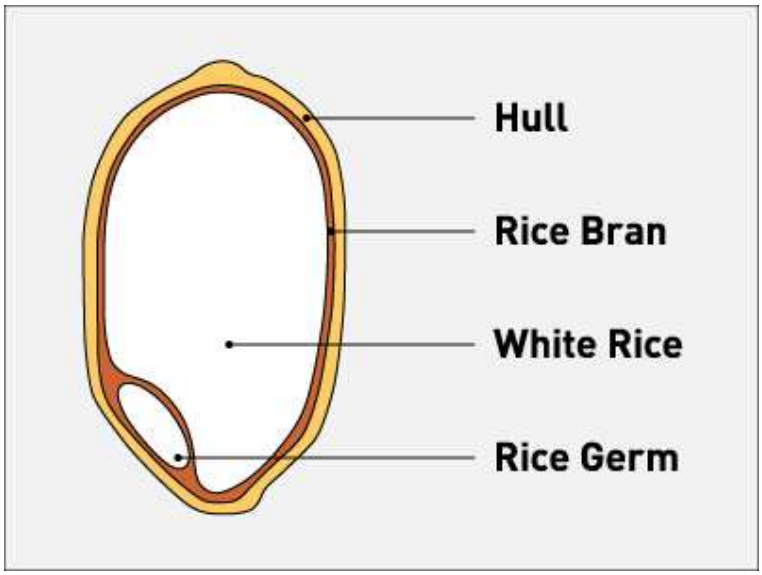

Figure 6: Depiction of Rice Kernel (japancentre.com)

For much of Haitian culture, broken rice signifies poverty - it is largely given to orphanages, schools, and charities (Furche, 2013). Because of its less expensive price, broken rice is associated with poverty around the world, even going by "poor man's rice," (cơm tấm A) in Vietnam. Interestingly, it is also gaining popularity as a unique rice dish in several countries. Cơm tấm A in Vietnam is often served with pork chops and eggs is a very popular fast food lunch time meal, and in Senegal, broken rice is used in their national dish ceebu jën ("rice fish"), which is a dish of broken rice, fish, and tomato sauce (Dall, 2019). In Bangladesh, khuder bhat is a sought-after delicacy of broken rice with onion, garlic, and spices, and in the U.S., broken rice is often served in the South under a different name – grits. Grits is a porridge dish that is typically made with coarsely ground cornmeal, but it is now in vogue to use broken rice as the grits. This type of arc for a food to go from "poor man's food" to the food of the elites is not uncommon – it can be seen in foods such as escargot, lobster, sushi, caviar, and chicken wings. It leads one to believe that social constructs often have as much of a role on the price tag of a food as do the flavor or functionality.

In 2018, Riceland and Tchako Ltd. began selling a new type of rice to Haitians at a discount price called Tigute. This rice is blended from the same lots of long-grain as Tchako branded rice, but it has 20% brokens as opposed to 4% brokens. Tchako rice still outsells at almost 2:1 s Tigute (about 11,000 metric tons to 4,000 metric tons from Riceland every eight to ten weeks), showing that Haitians still prefer to pay more for rice if it means paying a premium for rice with less brokens[2]. According to Riceland, Tigute is not increasing substantially in sales and is remaining consistently lower in sales than Tchako. Riceland does not presently know how much their two types of rice (Tchako and Tigute) are being sold for at retail, whether that be from open or closed bags, or if it is being advertised accurately. Tigute is typically sold $25 less per metric ton than Tchako from Riceland to Tchako S.A[3].

1.6 Basis for Two Studies (Chapters 2 and 3)

An objective of this study is to discover how brokens impact prices for Haitians among other factors such as chalkiness, location of harvest, brand trust, or color. Understanding the priorities of the Haitian rice consumers is crucial in creating a product that efficiently meets demands. In 2018, a study highlighted that Haitians would be willing to spend more on domestic and/or parboiled rice (Pavilus, 2018). Through collaboration with a University in Haiti, FONDWA, we were able to survey five major separate markets in Haiti in four regions (central, northern, southern, and "frontier" or near the border with the Dominican Republic), so we could better understand how the different consumer groups in Haiti prioritize their rice purchasing decisions. Through analyzing these rice samples, we can see how aligned preferences are with the actual qualities of the rice that was purchased. These rice samples will be purchased from

[2] Data collected through personal communication with rice exporting executive
[3] Data collected through personal communication with rice exporting executive

consumers in Haiti who had just bought the rice. That way, we will be able to utilize Revealed Preference. Revealed Preference reveals the preference of a consumer through their purchasing of a product or service rather than through Stated Preference or what they state their preference to be (Engstrom and Forsell, 2018). Revealed Preference is advantageous over Stated Preference because it captures actual behaviors and reduces the potential for hypothetical biases. Revealed Preferences capitalize on the basis that "actions speak louder than words".

In order to attain a representative sample of the Haitian population, we relied on the expertise of our colleagues at the Universite de Fondwa (UNIF). UNIF is the first, and only, rural university in Haiti whose "mission is to educate Haitians in order to create wealth in rural Haiti" (uFondwa.org, 2020). To attain a truly representative sample, we would need to go to every market in Haiti, but that is logistically and financially unfeasible. So, they determined that we needed to get data from consumers in the four major "departments" or regions in Haiti – West (Port-au-Prince Commune), Artibonite, Nord, and Nord-Est. Then within these departments, we needed to reach the major markets in each of these. In the West region, the two major markets, Petion-ville and Croix-des-bouquets; in Artibonite, the major market of Pont-Sonde; in Nord, the major market of Cap-Haitien; and in Nord-Est, the major market of Ouanaminthe (Fronteir) were chosen as the places of investigation. These markets were strategically chosen by the local team at UNIF with three goals of choosing markets that were diverse, representative of Haiti, and feasible.

Traditionally, brokens are priced 20-40% less on the open market than whole rice, so it is a logical place to look for ways to increase the sales for discounted rice containing a higher percentage of broken kernels (USDA, 2020). Often times, the cheapest products are sold in super markets, often in urban areas, so this is undoubtedly a problem for some Haitian farmers

Figure 7: Map of Haiti with Market Locations (University of Arkansas Division of Agriculture, 2021)

and other rural citizens (Kaufman et al. 1997). The idea of opportunity cost would still cause one to believe that Haitians are rational consumers and simply believe that spending more for the higher quality rice is a better alternative than eating cheaper rice of perceived less quality. But is it really less quality rice? The nutrition is relatively the same, with the aesthetics of the rice being the only thing that is potentially affected. If the aesthetics of the rice were not worsened, a rational consumer would buy a cheaper option of rice all else being equal.

By surveying Haitians to understand their preferences better, we can learn how strong of an impact changing the level of brokens in the rice would have on a representative sample of the Haitian population. Supplemented with gaining an understanding of peoples' willingness to pay in regards to the level of brokens in their rice, we can gain an understanding of the optimal level of brokens to sell to Haitians, many of which are food insecure. The sensory study of evaluating

rice-eating consumers' willingness to pay for rice of varying brokens, we can have a verified basis for determining the percentage broken that is optimal to reaching consumers who prefer discounted rice. While this sensory study does not perfectly align with Haiti, given that it was performed in the U.S., it does give an understanding of how important brokens are before and after purchase. The original goal of testing Haitians' sensory preferences of rice in conjunction with their market preferences was deemed infeasible because of travel restrictions, therefore we determined that testing Caribbean's sensory preferences would suffice. However, due to COVID-19, this was also not possible as the population in the U.S. that we intended to test was mostly no longer in the area for the time being. That is why the sensory study's focus shifted to testing rice-eating consumers' preferences of broken rice both in its raw and cooked forms, which has not been conducted before and adds an interesting perspective.

By understanding the impact that brokens have on the consumer in their raw and cooked forms, we can better our knowledge as to why brokens are so heavily discounted. If consumers have difficulty in discerning increased brokens in cooked rice, then it would seem that it is not the functionality or cooked attributes of brokens that decrease the price. If consumers can discern the difference in raw rice as a result of brokens, then that would mean that it is the aesthetics of the raw rice that is largely driving the price down.

Given that this survey was conducted during the global pandemic of COVID-19, we included two questions concerning the consumers purchasing habits and the impact it has had on local prices. We included this both to gain interesting insight into the impact COVID-19 has had on a specific country and to ensure that we accounted for its impact in our data analysis. How coronavirus has affected the purchasing decisions of food can be seen around the world as stores have struggled to maintain consistent supplies of essential food and other goods as reported by

populations worldwide. Nielsen Retail Measurement Services reported from the total U.S. outlets combined that consumers have purchased an increased 25.3% of rice since February 29, 2020. However, we do not have access to this sort of data in Haiti, so asking questions in our survey will prove to be a small case study of Haiti during this pandemic.

1.8 Hypotheses and Objectives

In conducting two separate studies, one in Haiti with economic preference focus and the other one in America with a sensory preference focus, there were some parallels that drove the overarching study. The collaboration of the two studies created the need for multiple objectives and hypotheses to be considered. Overall, we wanted to discover how great an impact brokens have on Haitian rice consumers' preferences and willingness to pay. After noticing that there is a lack of differentiation of brokens and price on imported rice in Haiti, it became clear that there is a gap in the Haitian rice market for a discounted imported rice with increased broken percentage. This gap in the market was the main point of research that this study set out to investigate. Furthermore, supplemented by the sensory data, greater conclusions as to how brokens are interpreted by consumers before and after purchase could be gained.

One hypothesis of this study was that Haitians pay less money for rice with higher levels of brokens. Since the study purchased actual samples of rice to then be analyzed for broken percentage, we could see how brokens impact the actual price paid for the rice. This hypothesis was important because if it is true, it can be used to push for a discounted rice with higher broken percentage into the Haitian market. If Haitians pay less money for brokens and there is a portion of their country who would pay less for food because of financial reasons, then brokens can be used as a means of reducing that price.

A second hypothesis of this study was that brokens are not the main determining factor in consumer rice purchasing decisions in Haiti. This hypothesis was created because of previous findings (in Haiti and elsewhere) that brokens are often not the most important attribute for consumers. It was important because if true, it would indicate that there are other attributes (intrinsic or extrinsic) that are driving the price of rice, and that brokens can be increased without an equal decrease in demand. As producers and importers are concerned with demand, this would be important to consider if implementing a discounted higher broken percentage rice.

A third hypothesis was that rice-eating consumers are not impacted by their sensory perception of increasing levels of brokens (<40%). This hypothesis was tested both with raw and cooked rice, with different results somewhat expected. Based on a visual test, it is fairly easy to discern brokens in rice. However, when the rice is cooked, it is typically more difficult to discern those differences. This hypothesis was at the root of the issue tested in the sensory study – at what point (pre-purchase or post-purchase) are brokens negatively affecting consumers and the price of rice. In addition, by testing the consumers' perceptions of the rice in the same increments (5%, 10%, 20%, 30%, and 40%) of the raw and cooked rice, a break-point in acceptance could be better understood.

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Chapter 2: How Consumer Preferences of Broken Rice in Haiti Could Indicate a Need for Import Diversification

ABSTRACT

There is a large disconnect between the current state of Haiti and the imposed restrictions on brokens for Haitian rice imports. This study discovered through observing rice after-purchase that Haitians do not place a significant discount on brokens of imported rice. This indicates that there is a place in the market for rice with increased brokens with decreased price (as a result of decreased cost for the producers). A study such as this has not been done before in Haiti, and it enlightened the authors of the need for lessened restrictions on imported rice's brokens so as to give Haitians the ability to buy cheaper rice if that is what would be maximally beneficial for them. The authors also discovered that a high premium is placed on domestic rice, despite domestic rice having a significantly higher level of percentage broken (almost 50% maximally), further illustrating the small effect that brokens actually have on Haitian consumer rice preferences.

1. INTRODUCTION

Haiti has the lowest per capita Gross Domestic Product (GDP) ($1940) in the Western Hemisphere and is one of the most food insecure countries with 33% of its population needing food assistance and nearly half of the population, 49%, as being chronically undernourished (World Food Program, 2019). Coupled with Haiti's population increasing by roughly 4 million people since 1995 to a current population of 11.5 million, rice is the caloric staple in the Haitian

diet and accounts for 30% of daily caloric intake, increasing from 7% of average daily calorie intake in 1985 (FAO, 2018). While rice has become an increasingly important part of Haitians' diets, domestic rice production has not been able to keep up with the rising demand. The lack of sustained investment in agricultural production and post-harvest infrastructures have limited the growth of the domestic rice industry. The difference between demand and domestic production became so critical that in 1986 Haiti was forced to open its markets and import rice for the first time (Icart and Trapp, 1999). In 2016 it was estimated that 80% of rice consumption in Haiti was imported (Cochrane et. al, 2019). Rice imports improved food availability and decreased food insecurity, increasing per capita calorie availability by 11 percent between 1985 and 2011 (Cochrane et. al, 2019). Rice imports increased from 7,000 metric tons in 1985/86 to 25,000 metric tons in 1986/87, with the United States being the vast majority supplier (USDA, 2013). Rice imports increased to 140,000 metric tons by 1994 with the United States continuing to be the largest supplier. One of the main drivers of both the importation of rice into Haiti, American rice, into Haiti is that imported American rice is significantly cheaper than local Haitian varieties (citation above).

Although the United States produces less than 2% of the world's total rice crop, the U.S. rice production accounts for over 10% of the volume of globally traded rice and is the largest exporter of rice to Haiti (USDA, 2019). In 2019, the United States produced roughly 9.3 million metric tons (205 million cwt[4]), with Arkansas producing almost half of that at roughly 4.3 million metric tons (95.1 million cwt) (USDA, 2019). Riceland foods, the largest rice cooperative in the United States, is one of the largest exporters of rice to Haiti. Riceland exports

[4] Cwt is abbreviated "hundredweight" or 100 pounds, which is the standard unit of measurement for rice in North America

much of their rice, with their two top exporting nations being Mexico and Haiti. In 2018/2019, Mexico imported the most rice from America, over 823,000 tons, and Haiti imported over 442,000 tons of rice from America which was over 80% of the total Haitian rice supply.

Unfortunately, Haiti is prone to increasing frequency and intensity of natural disasters, and antiquated agricultural production systems food insecurity is still a policy and stability issue. Domestic rice yields have remained stagnant at roughly two tons per hectare (half of the international average) since 2000 as a result of: lack of maintenance of irrigation, declining quality of land, lack of skilled labor, small farm sizes and mills being too small and outdated technologically to be efficient, and farmers having diminishing crucial inputs such as working capital (interest rates for private financing are too high for most to pay), water access, and high quality seeds (Furche, 2019).

Increased food insecurity further manifested by the natural disasters which have severely impacted Haiti's ability to be food secure, with several tragedies occurring in the last decade. In 2010, a magnitude 7.0 earthquake occurred on January 12th only 25 km away from the capital city, Port-au-Prince, with aftershocks lasting through January 20th (Pallardy, 2020). This resulted in over three million (one-third of the country) to become homeless, severe destruction of infrastructure, roughly 316,000 deaths, and health crises as a result from the lack of sanitation. Because of Haiti's precarious situation on the seismic fault lines, the Enriquillo-Plantain Garden and Leogane faults, earthquakes are not isolated events and unexpectedly cause complete upheavals in domestic production (OXFAM, 2020). On top of these disasters, in 2015, a severe drought began in Haiti, hitting the Sud-Est, Nord-Ouest, and Artibonite rice producing regions the hardest and lasting through two production seasons. The drought resulted in losses of up to 70% of local agricultural production, worsening the already food-insecure situation 3.7 million

people in Haiti (OCHA, 2019). Crops such as rice were not only decimated during this drought, but soil deterioration, lack of high quality seeds, lack of capital to invest in land/infrastructure, and a generally lower quality of life caused by droughts all handicap future prospects of crops. Furthermore, because of Haiti's location directly in what is known as "Hurricane Alley", severe hurricanes have frequently caused massive destruction in Haiti (World Atlas, 2019). In 2016, Hurricane Matthew caused catastrophic flooding in Haiti, killing roughly 600 people and leaving roughly 35,000 homeless (Stewart, 2017).

After observing these harsh truths impacting Haiti's domestic rice production, one can see the underlying causes for what makes agricultural growth in Haiti so difficult. Economic hardships have compounded (and partially resulted from) the island nation being situated on the crux of tectonic plates connecting, "hurricane alley", and being negatively impacted by El Nino weather patterns. All three of these things have the power to bring natural disasters to a nation on their own, but having all three together of them in one portion of an island is foreboding. It creates an environment that is incapable of supporting a growing population effectively. Therefore, foreign aid is needed - not only in terms of charity and volunteered relief efforts, but also in giving people the ability to buy food at affordable prices.

Unlike most other staple crops like wheat or maize, rice is unique in that after it is harvested little processing is required after the milling process. Rice can be stored and transported in this milled conditions for many months. As such, visual qualities such as color, length and width play an important role in rice markets. Although Haiti is the poorest country in the Western Hemisphere it has some of the strictest importation standards for its staple crop, rice with a specification that imported rice contain no more than 4% broken kernels. Imported rice from the U.S. is restricted by importers' regulation, with seemingly strict standards imposed for a

country which is so food insecure. While these strict standards can result in homogenous rice in the market, it leaves little room for price discrimination for a lower grade, lower priced rice. It is likely that given the high standards which Haiti imposes for imported rice, and the subsequent price premium which that rice carries, that many of the poorest of the poor cannot buy the quantity of rice they need for their families due to lack of lower priced rice options. If Haiti imported a range of rice with varying qualities, vendors could segregate by levels of quality and charge different prices, leading to increased consumer and producer surplus.

The three largest Haitian rice importers, Accra (Mega), Tchako, and Rice Co (Bull) require that imported rice has a maximum percentage broken of 4%. After the hull and bran have been removed through processing, the resulting mass is milled rice, which is then separated into brokens and head rice. As an illustrative example, if 100 lbs of rice is delivered to a mill, the rough/paddy rice would be initially milled to remove the hull, trash, and bran. Because the hull, bran, and trash have mass, the resulting mass of rice would be < 100 lbs. The rice futures market in the United States is traded on an average of 70% milled rice, so the milled rice yield (MRY) would be 70 lbs for this example. Of this 70 lbs of remaining mass, some kernels would remain intact and some would break during the milling process. The rice futures market in the United States is traded assuming that 55% of the initial mass is whole kernels or head rice (HRY). Thus, in this example, there would be 55 lbs of head rice for a HRY of 55%. The difference between MRY and HRY is the percentage of the initial mass that are broken kernels. Thus, 70 to 55% results in 15% (in this case 15 lbs of brokens). The ratio 55/70 (HRY/MRY) is the standard on which the futures contracts are bought and sold in the United Sates. While the difference between Haitian (4%) broken standards and the US standards (15%) is large, it is even greater in magnitude when you consider plant physiology. Broken rice can have a large variance given its

dependence on climate, processing, genotype and genotype-by-environment interactions (Siebenmorgen, Nehus, & Archer, 1998 and Lyman et al 2016). Conversely, milled rice (the percentage of rice which is left after the bran and hull have been removed) gravitates around to around 70% regardless of climate, processing, genotype and genotype-by-environment interactions. Thus, the 11% difference between Haitian standards (4%) and US standards (15%) is actually much larger given the base is not 100% but 70%. Supplying Haiti with 4% broken imported rice is not only difficult but may contribute to the chronic hunger situation for this island's 11.5 million people.

Brokens are defined as rice kernels that are less than 75% of the length of the whole kernel of rice (USDA, 2009). Rice kernels are fractured mainly during the milling process while the bran is being polished off as a result of fissuring, cracking. Increased brokens can be a result of extent of milling, rapid moisture absorption, rapid drying, chalkiness, underdeveloped kernels, and environmental factors such as relative humidity, sudden temperature changes, and insect infestation (Siebenmorgen, Nehus, & Archer, 1998). Because brokens' are often perceived as being "poor" in appearance, they demand a significantly smaller price at retail – often selling at roughly 41% less than their whole kernel counterparts in 2020 (USDA, 2020). Broken rice provides the same nutritional content as non-broken rice and could even combat food insecurity more efficiently that non-broken rice because rice with a higher percentage of broken kernels could be offered at lower price.

Large, modern rice mills generally generate between 10-15% brokens, whereas smaller, generally less modern mills, like the ones found throughout Haiti, generate as much as 30% brokens (Muthayya et al. 2014). The US rice industry can mix broken and whole rice to any standard an importer requests, with an inverse relationship of price to brokens. Another issue

plaguing domestic rice production in Haiti is that the majority of their rice mills do not have the means or the technology to produce rice with low levels of brokens. These older, lower quality mills are incapable of reaching as high of a head rice yield as a result of less accurate processes of removing the bran and polishing the white kernels or due to poor moisture and temperature control during processing. Factors beyond milling such as quality of rice, storage and transportation conditions, and insects all play sizable roles in the amount of brokens produced as well. These factors are part of the current multitude of problems negatively affecting Haiti's domestic rice production. Previous studies have found that Haitians prefer domestic (yet lower quality rice) over imported rice (possibly due to its inflated cost associated with brokens standards) which results in domestic rice often being priced higher than imported rice (Pavilus, 2018). As such, low income consumers in Haiti (59% of the population) is forced to choose between expensive domestically produced rice and imported rice with inflated prices due to high quality standards (reliefweb.int, 2019). This choice leaves consumers with little choice in the effort to combat food insecurity, given rice is the staple crop of Haiti.

The objectives of this study were to estimate what quality characteristics Haitians value in domestic and imported rice via a non-hypothetical experiment. Specifically, do Haitians discount broken rice, and other quality attributes, in such a manner that strict regulations to keep imported broken rice out of domestic markets is warranted to be kept in place. Conversely, if we find that Haitian's do not discount broken rice then the strict quality import standards may be unwarranted and exacerbating food insecurity. The results of this study are unique in that this is the first study of its kind to compare reveled preferences to importation policies in a food security context. The results of this study can be used by rice importers/exporters, governments, and NGOs in an effort to alleviate food insecurity in Haiti using its staple crop as its vehicle.

2. MATERIALS AND METHODS

2.1 Participants and Surveys in Haiti

One unique aspect of this study is that preferences are revealed in a market setting and not elicited in a sensory laboratory or estimated via a hypothetical experiment. In similar studies in the past concerning rice preferences, rice samples were not gathered and analyzed to understand the inherent driving forces in consumers' rice purchasing decisions. While not novel in the marketing experimental literature, application of this method is novel in evaluating rice preferences in Haiti and mitigates the hypothetical bias often found in experimental auctions and contingent valuation and replaces a sensory lab setting for a real market purchase.

In cooperation with faculty at the University of Fondwa in Haiti, a total of 300 samples were collected across five separate, major rice markets across Haiti in an effort to obtain a representative sample of the Haitian population's preferences. Samples were collected from four departments (regions) West, Artibonite, Nord, and Nord-Est and two markets in the West to capture population heterogeneity between more and less affluent consumers (Petion-ville/Croix-des-Bouquets, Pont-Sonde, Cap-Haitien, and Ouanaminthe. A 15 sample pre-test survey was conducted in the University town of Fondwa for question validation; these preliminary observations were not used in the data analysis.

The survey was conducted by faculty from the University of Fondwa, in French and Creole, who traveled to each of the five markets and approached consumers after they exiting each of the target markets. Survey participants were asked if they had purchased rice that day in the market. If the participant said no, they were thanked for their time. If they said yes, the enumerator asked if they would like to take part in a paid survey which would include the faculty member purchasing 50 grams of the rice they just purchased for 200 Haitian Gourdes (HTG) or

roughly $1.86 USD. Given that the per capita income in Haiti is slightly more than $3 dollars per day (3.28USD per day), the compensation amount was sufficient enough to cover their time and small sample of rice purchased (World Food Program, 2019). A standard unit of measurement of rice in Haiti is the "marmit", which is roughly 300 grams. One-third of a marmit is called a "bwat let" (literally "milk box"), and enumerators paid participant and then took out a "milk box" filled it half way, the approximate 150 grams, and bagged the sample.

Once the participants' sample had been bagged and labeled, the participant was asked a series of questions pertaining to personal demographics and rice purchasing habits. These questions consisted of: gender, age, household size, highest level of education, and average household income. It was important to ascertain how much the participant paid for their entire rice purchase. Rice in Haiti is often sold from open bags which can present a problem as neither the rice nor the weights are standardized. However, as mentioned before there are common volumes (scoops) used in open rice bags, the marmit and the milk box. As such, participants were asked how many marmits or milk boxes were purchased so the enumerators could calculate total weight purchased. The participants were then asked how much they paid for that given volume. While this price was not observed, there would be little incentive for the participant to fabricate an answer as they had already been paid for the survey and there would be nothing to gain. From this, we could calculate how much each participant paid per kg of rice.

Enumerators then asked three questions with regards to the variety, origin, and brand of the rice which each participant had purchased. First, participants were asked if they knew the origin (either domestic or imported) of the rice they just purchased. This information is important as local Haitian rice often demands a premium price over imported, mostly American, rice. Local Haitian rice is typically easy to identify visually as it is more "off colored" than the more

homogenous white imported rice. Next, consumers were asked if they knew which variety they had just purchased. In Haiti domestic varieties like Shella and Shelda sell for 66% premium over the common imported American varieties Tchako and Mega (Cochrane et al., 2019). Lastly, each participant was asked if they knew which brand of rice they had just purchased. In each of the three questions, the participants were told it was okay if they did not know and that was an acceptable answer.

Next, participants were asked their preference for purchasing rice from sealed and labeled bags vs. the more common open bags. Sealed bags are often seen as equating to higher brand trust, quality, and origin as they are less like to be adulterated in open bags with lower quality rice. Rice purchased from open bags are often cheaper but also easier to be adulterated all along the supply chain. Participants were asked whether they purchased rice in sealed or open bags and then asked for their reasoning in that decision.

Participants were then asked how much rice their household consumed on average in a week. This was important to see if those that ate more rice had different preferences than those that did not eat as frequently. Also, it gave us validity that the respondent understands rice and their own preferences and were not making a decision that was very rare for them.

Participants were then asked a series of questions which pertained to attributes which they considered as being important when purchasing rice. Participants were given nine options and asked to rank their top five, 1 -5, with 1 being the most important. The options given were: cleanliness, price, amount of broken rice, amount of chalk, brand, origin, color, money on hand, and other. These options were designed to cover the many reasons Haitians balance when making a rice purchasing decision.

Two questions were asked in relation to the COVID-19 Pandemic. Participants were asked if they had changed their purchasing decisions because of COVID-19, and furthermore if they purchased more or less rice than usual. Participants were then asked if they had noticed prices of rice increase, decrease, or remain constant during the pandemic. Lastly, the survey tried to ascertain the participants' level of income which proved to be infeasible. Given the widespread poverty and lack of formal employment in Haiti many participants valued income as assets at home and not disposable income via a paycheck. This question proved so problematic it had to be discarded after the pre-test.

2.2 Market Justification

Figure 8: Map of Haiti with Market Locations (University of Arkansas Division of Agriculture, 2021)

Port-au-Prince is the most populace city in Haiti with around 2.62 million persons in the metro and growing (around 27% of Haiti's total population) (worldpopulationreview.com, 2020).

As the most populated and diverse area in Haiti, two major markets in Port-au-Prince: Croix-de-Bouquet and Petionville were chosen to administer the survey. A determining factor in these market selections was a National Coordination of Food Security (CNSA) government document citing these as two markets as the most important Port-au-Prince rice destinations for the rice value chain (Valcourt, 1996). Both market districts within Port-au-Prince have very large populations (Croix-de-Bouquet at ~300,000, and Petionville at ~350,000), but where Croix-de-Bouquet is known to be a less affluent suburb, Petionville is known as the more affluent and cultural capital of Port-au-Prince. These divergent markets were chosen in an attempt to capture the diversity of Port-au-Prince consumers.

The Artibonite valley in the central region of Haiti is the largest producer of domestic rice as well as the home to the third largest population center in Haiti, Gonaives. Ponte-Sonde was chosen as a market because of its high levels of domestic rice locally as well as its location as an important crossroads between the two largest Haitian cities, Port-au-Prince and Cap-Haitien. Cap-Haitien was chosen as a market to survey as it is the second largest "urban" center in Haiti. Cap-Haitien is situated on the northern coast with a distinct culture and history.

Ouanaminthe is situated on the border between Haiti and the Dominican Republic, and this area has a unique language, culture, and dietary habits. Dominican rice is imported all along the Haitian border, with a reputation of having a large amounts of broken rice. The National Institute of Applied Sciences (INSA) of Paris measured some of this exchange in 2002, observing broken rice as a "key product" of exchange in Ouanaminthe between the Dominican Republic and Haiti, mostly in the form of informal exchanges, of which approximately 70% was informally exported from Dominican Republic into Ouanaminthe markets (Damais, 2002). Furthermore, Ouanaminthe is the largest of the border communes with a population of around

100,000. It is also an important part of the value chain for both domestic and imported rice's distribution in the North-West of Haiti.

2.3 Rice Analysis

Rice samples were analyzed at the University of Arkansas Food Science Rice Lab where all 300 samples of rice were individually analyzed using two primary forms of analysis. Since the level of brokens in the rice was a priority for the study, two means for analysis were used and verified. The primary separation method, separating whole from broken, was using an indented cylinder grader, Satake Test Rice Grader. Broken grains are lifted by the indentations and by the cylinder's rotary motion whereas full-length kernels are not. Brokens will fall from the indents into an adjustable trough, which can be discharged separately from the rest of the whole-grain rice. The angle of the trough, the cylinder chosen, and the speed of the rotation all factor into the brokens that are collected, and they were all adjusted to the appropriate levels given the long-grain rice that was being tested. Each individual sample was tested through this method, then the broken rice was weighed as well as the head rice to determine a percentage of brokens by weight in the sample using the following equation:

$$P_{br} = (W_{br} / W_s) * 100,$$

where P_{br} is the proportion of breakage rice (%), W_{br} is the weight of brokens (g) and W_s is the initial weight of the rice sample used (g).

In order to gather data on each rice sample for attributes such as average length, average width, chalk, brokens, and discoloration, each individual sample was also analyzed by the SC5000 SeedCount machine. From each sample, we used a random 20 grams to estimate various quality attributes. The SeedCount method used this 20 gram sample to create a sub-

sample to process a 500-kernel sample and employed a flatbed scanner to create a digital image of each individual rice kernel. Kernel-by-kernel data was taken for each of the 500-kernel sample and then aggregated for an average score for a given sample. The SeedCount terminal setup uses a tray with individual slots for each of the 500 kernel sample with half of the kernels laying horizontally allowing for a width measurement with the other half the of sample laying vertically to measure length. The SeedCount image analysis software uses a comparison of each kernels length with the average sample length to determine broken percentage (defined as less than three-fourths the sample average length). Thus, from the Seed Count results we could quantify what the literature has defined as the most important search attributes for rice in Haiti; width, length, percent broken and chalkiness for each of the 300 total rice samples. This, combined with the data from the Satake Rice Grader, provided accurate analyses for all attributes of interest for each rice sample.

2.4 Hedonic Price Model

Hedonic pricing is rooted in Lancaster's theory of demand that states that a product can be described as a bundle of characteristics or attributes (Lancaster 1971), and that therefore the price consumers are willing to pay for a product is a function of a combination of the attributes of the product. Consumers make their purchasing choices based on the bundle of attributes that define each product, and the price they pay is considered the revealed in their willingness to pay for a product (Lusk and Shogren 2007). Aside from the characteristics of the products, consumers' socioeconomic status also impacts their choices. Thus, besides the physical characteristics of rice, we also account for the impact of selected socioeconomic characteristics on the price consumers are willing to pay for rice. This included categorizing the consumers into income brackets of low, medium, and high, defined as below the poverty line (7,750

Gourde/month) for low, above average income for high (16,688 Gourde/month), and medium in between those two values (worldbank.org, 2020).

The hedonic price model assumes that the price P_i that consumer *i* is willing to pay is a function of rice quality attributes, represented by vector X_i, socioeconomic characteristics and location of consumer *i*, represented by vector Z_i, and market location represented by a vector of dummy variables L.

$$P_i = \alpha X_i + \beta Z_i + \gamma L + \varepsilon_i \quad (1)$$

Different model specifications were tested, including models with interaction between rice quality variables and socioeconomic characteristics of respondents ($X_i * Z_i$), and subsample models by markets (name the markets here) (, source (imported versus domestic), income level (low, middle, and high income).

The model is estimated using a log-log functional form using Ordinary Least Squares (OLS), which means that the coefficients are interpreted as being along a continuum of elasticities. Accordingly, the coefficients β_j associated with the attribute j is as following:

$$\beta_j = \frac{\frac{\partial P_i}{P_i}}{\frac{\partial x_j}{x_j}} \quad (2)$$

The marginal price of rice attribute j is derived from equation 2 as follows:

$$\frac{\partial P_i}{\partial x_j} = \beta_j \frac{P_i}{x_j} \quad (3)$$

Where P_i is the price paid by consumer *i*, β_j the coefficient of attribute *j* estimated from the hedonic model, and x_j represents the mean value of attribute *j*.

3. RESULTS

Table 1: Summary Statistics of Pooled and Location Quality Attributes
"a" signifies not significantly different ($p < 0.05$) than pooled, "b" signifies significantly different than pooled

	Pooled	Ponte-Sonde	Ouanaminthe	Cap-Haitien	Petion-Ville	Croix des bouquets
Price/kg (USD)[5]						
Min	0.46	0.46 a	0.81 b	0.79 b	0.85 b	0.85 a
Mean	1.13	1.10 b	1.13 a	1.04 b	1.07 b	1.31 b
Max	5.08	2.54 b	2.54 b	2.12 b	2.12 a	5.08 a
Length (mm)						
Min	6.55	6.68 b	6.63 b	6.6 b	6.61 a	6.55 a
Mean	7.09	7.03 b	7.20 a	7.04 a	7.22 a	6.96 a
Max	8.08	7.73 a	7.79 b	7.69 b	7.79 a	8.08 b
Width (mm)						
Min	2.04	2.1 b	2.04 a	2.07 b	2.04 b	2.09 a
Mean	2.37	2.36 a	2.38 a	2.38 a	2.39 a	2.36 a
Max	2.54	2.52 a	2.52 b	2.52 b	2.54 a	2.54 a
Chalk Impact (0-100)						
Min	0	0 a	0.21 b	0.09 b	0.2 a	0 b
Mean	2.71	2.82 a	2.49 a	3.1 a	2.87 a	2.26 a
Max	21.03	6.71 b	8.3 b	21.03 b	5.41 a	8.27 a
Total Discolored (%)						
Min	15.3	36.3 b	33.1 b	33.6 a	31.5 a	15.3 a
Mean	51.6	54.7 a	44.1 a	47.2 a	54.7 a	57.4 a
Max	87.3	86.1 b	85.4 b	87.3 a	86.2 a	85.6 b
Broken (%)						
Min	3.0	3.7 a	3.0 b	3.9 b	3.7 b	4.4 a
Mean	15.9	24.3 b	13 b	12.9 b	15.7 a	13.8 a
Max	48.1	48.1 a	47.6 b	46.5 b	47.6 b	41.2 b
Observation	292	59	60	59	57	57

[5] Exchange rate as of June 24, 2020

Table 1: Summary Statistics of Income and Imported/Domestic Quality Attributes
"a" signifies not significantly different ($p < 0.05$) than pooled, "b" signifies significantly different than pooled

	Pooled	Low Income	Medium Income	High Income	Imported	Domestic
Price/kg (USD)[6]						
Min	0.46	0.46 a	0.62 a	0.85 b	0.46 a	0.62 a
Mean	1.13	1.10 a	1.12 a	1.14 a	1.03 b	1.27 b
Max	5.08	2.54 b	2.54 a	5.08 a	5.08 a	2.54 a
Length (mm)						
Min	6.55	6.68 b	6.6 a	6.55 a	6.9 a	6.55 a
Mean	7.1	7.08 b	7.10 a	7.09 a	7.10 a	7.07 b
Max	8.08	7.54 b	7.79 a	8.08 a	7.51 a	8.08 a
Width (mm)						
Min	2.04	2.1 b	2.04 a	2.04 a	2.14 a	2.04 a
Mean	2.37	2.37 a	2.37 a	2.37 b	2.37 a	2.38 a
Max	2.54	2.52 b	2.52 a	2.54 a	2.45 a	2.54 a
Chalk Impact (0-100)						
Min	0	0 b	0.21 b	0 a	0.25 a	0 a
Mean	2.7	2.63 b	2.54 b	2.81 a	3.11 b	2.10 b
Max	21.03	6.71 b	8.3 b	21.03 b	8.27 b	21.03 a
Total Discolored (%)						
Min	15.3	36.4 b	33.1 b	15.3 a	30.7 a	15.3 b
Mean	51.6	53.90 b	50.69 a	51.69 a	44.16 a	62.72 a
Max	87.3	86 b	86.1 a	87.3 a	60.4 a	87.3 a
Broken (%)						
Min	3.0	3.7 a	3.0 a	3.7 a	3.02 a	5.88 b
Mean	15.9	18.0 a	15.1 a	16.0 a	10.47 b	24.34 b
Max	48.1	48.1 a	47.6 a	47.6 a	31.31 b	48.08 a
Observations		28	93	171	176	116

[6] Exchange rate as of June 24, 2020

Tables 1 and 2 show the ranges and the means of the quality attributes that were tested by the seedcount and satake rice grader by each subsample; location, income, imported/domestic, and total (pooled). These data show that the ranges for length and width were similar across all subsamples. Given that Haitians have a preference for long-grain rice, it would be intuitive that both imported and domestic rice that are similar in average length (Pavilus, 2018). This gives a range of 1.42 mm, a relatively small range. The average length across all samples was 7.1 mm. Width varied from 2.04 mm to 2.54 mm, with a mean width of 2.4 mm. Chalk Impact, a measure of the chalkiness of the rice sample in the SeedCount that gives a score of 0 – 100 (0 being no chalk and 100 being all chalk), was observed as having very similar mean scores across location, imported, and income brackets – between 2.10 and 3.11. This indicates that the samples had relatively low chalkiness, indicating that Haitians either prefer rice with low chalk or the domestically produced rice is naturally low in chalk, as imported rice generally is standardized to having low chalk (USDA, 2009). The range for chalk impact scores was between 0 and 21.03, with the rice at the top of the scoring 21.03 also being a domestic rice purchased in Cap-Haitien by a high-income consumer. The percentage of the rice samples that were discolored was high across the board, but domestic rice was found to be highly correlated with a higher percentage discolored. As seen in the percentage broken, there was a fairly wide range of 3.0% to 48.1%. The only variable that changes the mean significantly from the pooled mean of 15.9% broken was imported vs. domestic – imported rice averaged 10.47% broken while domestic rice averaged 24.34% broken. This makes sense as Haitian rice mills are generally less capable of producing a high-quality, low percentage broken rice.

3.1 Quality Impacts

3.1.1 *Percentage Broken*

Table 3: Pooled Models

Dependent Variable: Ln Gourde/Kg					
	Model 1	Model 2	Model 3	Model 4	Model 5
Ln Length (mm)	**-0.096**	**-0.049**	**-0.104**	**0.084**	**0.129**
	(0.564)	(0.544)	(0.613)	(0.562)	(0.580)
Ln Width (mm)	**0.386**	**0.608***	**0.596***	**0.442**	**0.458**
	(0.325)	(0.331)	(0.347)	(0.324)	(0.327)
Ln Chalk Impact	**0.032****	**0.033****	**0.035****	**0.026****	**0.024****
	(0.016)	(0.016)	(0.014)	(0.011)	(0.011)
Ln Broken (%)	**0.041***	**-0.100*****	**-0.099*****	**-0.082*****	**-0.079*****
	(0.024)	(0.030)	(0.030)	(0.028)	(0.028)
Ln Discolored (%)	**0.016**	**-0.021**			
	(0.058)	(0.058)			
Imported		**-0.270*****	**-0.268*****	**-0.386*****	**-0.383*****
		(0.044)	(0.043)	(0.042)	(0.042)
Croix des Bouquets				**0.052**	**0.063**
				(0.047)	(0.050)
Ouanaminthe				**-0.063****	**-0.063****
				(0.030)	(0.030)
Petion-ville				**0.062****	**0.062****
				(0.030)	(0.030)
Ponte-sonde				**-0.329*****	**-0.326*****
				(0.041)	(0.041)
Med Income					**0.063**
					(0.048)
High Income					**0.059**
					(0.050)
Constant	**4.416*****	**4.798*****	**4.833*****	**4.687*****	**4.523*****
	(1.345)	(1.367)	(1.417)	(1.320)	(1.374)
Observations	292	292	292	292	292
R	0.025	0.161	0.161	0.398	0.403
Note:		*p<0.1; **p<0.05; ***p<0.01			

Table 3 presents the results of the pooled (non-subsample) fixed effects models. The results for broken are significant ($P<0.05$) across all specifications and indicate that as percentage of broken increases the price paid for that sample decreased, with the expectation of model 1. Model 1, is non-sensical in that it suggests that as brokens increase so does price. This is explained by the fact that on average domestic rice contains more brokens (13.87 percent more, Table 2) than imported rice. Further, given the large body of literature which suggests that Haitians prefer domestic rice, model 1 has a collinearity issue between imported and broken which is resolved in models 2-5 with the inclusion of an imported dummy (which is always significant ($P<0.01$) and negative). The results of the broken coefficients in the pooled models 2-5 seem to suggest that while brokens significantly impact rice price, they play a small role in shifting price. The largest broken effect in models 2-5 (model 2) suggests that for every 1% increase in broken rice that price would decrease only by 0.1 percent. To put this in context the range between the highest and lowest percentage of brokens in our sample was 45.1% (Table 3), would only equate to a 4.51 percent reduction in price. While statistically significant, these results suggest that consumers in Haiti may have an aversion to broken rice, but it is not the main driver of prices. Importantly, these results suggest that rice with high percentage of brokens are still being purchased with only a minimal price discount.

While the pooled models on Table 3 provide snapshots for Haiti in general, they do not provide broken specific coefficients for different segments of the Haitian population. Given that different markets across Haiti likely represent heterogenous preferences for rice Tables 4 and 5 estimate market specific broken coefficients. Table 4 (all models) are plagued with the same collinearity issues that model 1 suffers between domestic rice (with high average broken levels relative to imported) and broken percentage. As such, Table 5 (all models) remedies this

collinearity issue by including an imported variable. With the exception of the market in Petionville, Table 5 indicates that brokens are play an insignificant (P>0.10) role in determining rice price. Even in Petion-ville, where the difference between the maximum and minimum broken percentage across samples is 43.9 percent (Table 1), the estimate coefficient on Table 5 would suggest a price difference of only 4.25% (43.9*-0.097) indicating that even amongst extremes that brokens play a only a very minor role in rice pricing. In all other locations broken percentage had almost no effect on rice price. One argument for this seemingly counterintuitive result is that consumers cannot tell the difference between samples with varying levels of brokens in raw rice and thus rice sellers take advantage of their lack of ability to discriminate. This could be likely explain the small differences of brokens between samples but Table 1 indicates that in each of the five markets the minimum difference between the maximum and minimum samples was 36.8 percent (Croix des bouquets) which even a novice eye could likely detect the difference.

Income could be a factor where broken rice manifests itself as being inferior, with higher income consumers being willing and capable of paying higher prices for higher quality rice. Tables 8 and 9 estimate the effects of income subsamples and their effects on rice price. Again, high income was defined as above 16,688 Gourde/month (216.82 USD/month), low income defined as below 7,750 Gourde/month (100.69 USD/month) and medium income defined as in between these two numbers. These numbers were determined as 7,750 Gourde/month is the poverty line in Haiti, and 16,688 Gourde/month is considered above the average income in Haiti Table 9 indicates that only high income consumers pay less for increased broken rice. Previous research has shown that low levels of brokens are seen as a symbol of good quality, and oftentimes, wealth for rice consumers (Tomlins et al., 2007). As importantly, these results would

suggest that medium and low-income consumers, especially important for food security issues, do not discount (P>0.10) broken rice. These results should signal to rice importers, NGOs and government policy makers that low-income consumers, at least in this study, are indifferent about broken rice and likely would be willing to purchase rice with a higher percentage of broken kernels for a cheaper price. This could have positive food security implications as samples in this study had broken rice percentages in the high 40 percent range and broken rice can be sourced cheaper than whole kernel rice. This would seem to imply you could reduce food insecurity by importing lower quality rice.

Tables 11 and 12 estimated how rice price changed with variations in broken percentages across imported and domestic rice. Interestingly, there was no statistical (P>0.10) effect of broken rice on domestic rice price. This would seem to be positive news for the Haitian rice producing community as consumers will not discount broken rice which may be a function of antiquated milling and harvesting equipment in Haiti. Conversely, it was found in both Tables 11 and 12 that there is a discount associated with higher percentages of broken rice for imported rice. This discount, although small (0.073% and 0.07% in Tables 11 and 12, respectively) likely is reflected from the perception that imported rice is of a higher quality and thus the standards associated with it are likely internally higher for consumers. Again, these findings are robust with the collective findings for all model specifications for brokens, they effect price but only marginally. Important from a food security standpoint, the difference between the highest and lowest brokens for imported rice (Table 1) was 28.29% which would indicate a price reduction of 2.06 and 1.98% from the results on Tables 11 and 12, respectively. This should signal rice importers in Haiti to start sourcing cheaper rice with higher percentage brokens to help combat the high food insecurity rate in Haiti.

Table 2: Location Model with Discolored

Dependent Variable: Ln Gourde/Kg

	Cap Haitien	Croix des Bouquets	Ouanaminthe	Petion-ville	Ponte-sonde
Ln Length (mm)	**-0.331**	**0.892**	**0.785**	**-0.511**	**0.126**
	(0.767)	(2.081)	(0.694)	(1.242)	(0.368)
Ln Width (mm)	**0.213**	**0.631**	**0.406**	**0.135**	**-0.044**
	(0.492)	(1.350)	(0.374)	(0.682)	(0.345)
Ln Chalk Impact (0-100)	**0.001**	**0.019**	**0.03**	**0.041**	**0.017**
	(0.023)	(0.051)	(0.036)	(0.040)	(0.011)
Ln Broken (%)	**0.084***	**0.210*****	**0.034**	**0.062**	**0.044**
	(0.045)	(0.074)	(0.036)	(0.072)	(0.038)
Ln Discolored (%)	**-0.063**	**0.224**	**0.055**	**-0.158**	**-0.038**
	(0.072)	(0.180)	(0.078)	(0.224)	(0.064)
Constant	**5.224*****	**1.163**	**2.535***	**6.172*****	**4.416*****
	(1.625)	(5.526)	(1.502)	(1.969)	(0.755)
Observations	59	57	60	57	59
R^2	0.11	0.165	0.069	0.047	0.07
Note:	*p<0.1; **p<0.05; ***p<0.01				

Table 3: Location Model with Imported

	Imported				
Dependent Variable: Ln Gourde/Kg					
	Cap-Haitien	Croix des bouquets	Ouanaminthe	Petion-ville	Ponte-sonde
Ln Length (mm)	**0.05**	**1.994**	**0.72**	**0.046**	**0.044**
	(0.626)	(2.473)	(0.588)	(0.566)	(0.380)
Ln Width (mm)	**0.445**	**1.101**	**0.418**	**0.117**	**-0.161**
	(0.404)	(1.637)	(0.355)	(0.438)	(0.317)
Ln Chalk Impact (0-100)	**0.014**	**-0.001**	**0.021**	**-0.025**	**0.022***
	(0.023)	(0.031)	(0.037)	(0.025)	(0.012)
Ln Broken (%)	**-0.013**	**-0.045**	**-0.031**	**-0.097***	**0.053**
	(0.041)	(0.077)	(0.056)	(0.052)	(0.036)
Imported	**-0.259*****	**-0.553*****	**-0.103**	**-0.602*****	**0.019**
	(0.072)	(0.114)	(0.080)	(0.062)	(0.067)
Constant	**4.483*****	**0.476**	**3.097****	**5.325*****	**4.495*****
	(1.235)	(6.155)	(1.425)	(1.264)	(0.873)
Observations	59	57	60	57	59
R^2	0.29	0.404	0.081	0.755	0.069
Note:	*p<0.1; **p<0.05; ***p<0.01				

Table 4: Location Model with Imported and Income

Imported and Income					
Dependent variable: Ln Gourde/Kg					
	Cap-Haitien	Croix des bouquets	Ouanaminthe	Petion-ville	Ponte-sonde
Ln Length (mm)	**-0.035**	**2.508**	**0.749**	**0.024**	**0.012**
	(0.699)	(2.683)	(0.651)	(0.562)	(0.392)
Ln Width (mm)	**0.433**	**1.103**	**0.550***	**0.076**	**-0.302**
	(0.382)	(1.674)	(0.311)	(0.464)	(0.391)
Ln Chalk Impact (0-100)	**0.007**	**-0.015**	**0.036**	**-0.027**	**0.022***
	(0.024)	(0.039)	(0.038)	(0.025)	(0.012)
Ln Broken (%)	**-0.002**	**-0.043**	**-0.025**	**-0.096***	**0.063**
	(0.042)	(0.086)	(0.054)	(0.054)	(0.043)
Imported	**-0.249*****	**-0.555*****	**-0.104**	**-0.610*****	**0.026**
	(0.070)	(0.116)	(0.086)	(0.063)	(0.071)
Medium Income	**0.098**	**0.134**	**0.149****	**-0.064**	**0.071**
	(0.113)	(0.120)	(0.066)	(0.056)	(0.049)
High Income	**0.056**	**0.12**	**0.032**	**-0.069**	**0.043**
	(0.106)	(0.152)	(0.060)	(0.048)	(0.028)
Constant	**4.564*****	**-0.618**	**2.840***	**5.472*****	**4.596*****
	(1.338)	(6.620)	(1.495)	(1.267)	(0.954)
Observations	59	57	60	57	59
R^2	0.315	0.421	0.203	0.757	0.1
Note:	*p<0.1; **p<0.05; ***p<0.01				

Table 7: Income Model with Discolored

Income			
Dependent Variable: Ln Gourde/Kg			
	Low Income	Medium Income	High Income
Ln Length (mm)	**-0.462**	**-0.469**	**0.201**
	(2.610)	(0.613)	(0.895)
Ln Width (mm)	**0.057**	**-0.529**	**1.140****
	(1.868)	(0.378)	(0.476)
Ln Chalk Impact (0-100)	**-0.044**	**0.084****	**0.022**
	(0.074)	(0.034)	(0.022)
Ln Broken (%)	**0.037**	**0.056**	**0.051***
	(0.091)	(0.051)	(0.028)
Ln Discolored (%)	**-0.269**	**-0.071**	**0.075**
	(0.233)	(0.079)	(0.101)
Constant	**6.519**	**6.198*****	**2.944**
	(6.601)	(1.217)	(2.152)
Observations	28	93	171
R^2	0.045	0.075	0.05
Note:		*p<0.1; **p<0.05; ***p<0.01	

Table 8: Income Model with Imported

	Imported		
Dependent variable: Ln Gourde/Kg			
	Low Income	Medium Income	High Income
Ln Length (mm)	**-0.842**	**-0.829**	**0.4**
	(2.468)	(0.598)	(0.985)
Ln Width (mm)	**1.836**	**-0.624***	**1.506*****
	(1.948)	(0.367)	(0.529)
Ln Chalk Impact (0-100)	**-0.024**	**0.094*****	**0.021**
	(0.061)	(0.035)	(0.017)
Ln Broken (%)	**-0.161**	**-0.033**	**-0.128*****
	(0.103)	(0.059)	(0.033)
Imported	**-0.310***	**-0.198****	**-0.328*****
	(0.176)	(0.076)	(0.053)
Constant	**5.404**	**7.044*****	**3.189**
	(6.264)	(1.336)	(2.269)
Observations	28	93	171
R^2	0.14	0.157	0.238
Note:		*p<0.1; **p<0.05; ***p<0.01	

Table 5: Income Model with Imported and Location

Imported and Location			
Dependent variable: Ln Gourde/Kg			
	Low Income	Medium Income	High Income
Ln Length (mm)	**-3.215**	**-0.261**	**0.345**
	(2.365)	(0.506)	(0.947)
Ln Width (mm)	**-0.84**	**-0.439**	**1.079****
	(1.950)	(0.339)	(0.489)
Ln Chalk Impact (0-100)	**-0.06**	**0.063****	**0.018**
	(0.069)	(0.026)	(0.014)
Ln Broken (%)	**-0.092**	**-0.027**	**-0.113*****
	(0.130)	(0.049)	(0.034)
Imported	**-0.540***	**-0.391*****	**-0.383*****
	(0.258)	(0.088)	(0.051)
Croix des bouquets	**0.092**	**0.025**	**0.112**
	(0.206)	(0.069)	(0.080)
Ouanaminthe	**-0.048**	**-0.001**	**-0.078****
	(0.184)	(0.065)	(0.033)
Petion-ville	**0.208**	**0.006**	**0.086****
	(0.181)	(0.056)	(0.039)
Ponte-sonde	**-0.395**	**-0.382*****	**-0.270*****
	(0.248)	(0.099)	(0.044)
Constant	**12.384***	**5.988*****	**3.695***
	(6.340)	(1.104)	(2.214)
Observations	28	93	171
R^2	0.442	0.42	0.454
Note:		*p<0.1; **p<0.05; ***p<0.01	

Table 6: Imported/Domestic Model with Discolored

Discolored		
Dependent variable: Ln Gourde/Kg		
	Imported rice	Domestic rice
Ln Length (mm)	**1.058**	**-1.093**
	(0.851)	(0.895)
Ln Width (mm)	**0.378**	**1.609*****
	(0.481)	(0.597)
Ln Chalk Impact (0-100)	**0.009**	**0.031**
	(0.020)	(0.029)
Ln Broken (%)	**-0.080*****	**-0.163****
	(0.027)	(0.071)
Ln Discolored (%)	**0.024**	**-0.215**
	(0.072)	(0.157)
Constant	**2.369**	**6.952*****
	(2.243)	(1.537)
Observations	176	116
R^2	0.063	0.167
Note:	*p<0.1; **p<0.05; ***p<0.01	

Table 7: Imported/Domestic Model with Location

	Location	
Dependent variable: Ln Gourde/Kg		
	Imported rice	Domestic rice
Ln Length (mm)	**1.092**	**-0.602**
	(0.935)	(0.518)
Ln Width (mm)	**0.401**	**0.547**
	(0.489)	(0.379)
Ln Chalk Impact (0-100)	**0.001**	**0.008**
	(0.015)	(0.019)
Ln Broken (%)	**-0.073****	**0.019**
	(0.029)	(0.054)
Croix des bouquets	**-0.021**	**0.263*****
	(0.052)	(0.097)
Ouanaminthe	**0.008**	**-0.138***
	(0.029)	(0.075)
Petion-ville	**-0.02**	**0.289*****
	(0.027)	(0.083)
Ponte-sonde	**-0.067**	**-0.291*****
	(0.055)	(0.067)
Constant	**2.373**	**5.569*****
	(2.202)	(1.200)
Observations	176	116
R^2	0.07	0.669
Note:	*p<0.1; **p<0.05; ***p<0.01	

Table 8: Imported/Domestic Model with Location and Income

Location and Income		
Dependent variable: Ln Gourde/Kg		
	Imported rice	Domestic rice
Ln Length (mm)	**1.17**	**-0.673**
	(0.966)	(0.527)
Ln Width (mm)	**0.444**	**0.422**
	(0.488)	(0.428)
Ln Chalk Impact (0-100)	**-0.002**	**0.005**
	(0.015)	(0.019)
Ln Broken (%)	**-0.070****	**0.036**
	(0.030)	(0.056)
Croix des bouquets	**-0.015**	**0.289*****
	(0.058)	(0.093)
Ouanaminthe	**0.011**	**-0.133***
	(0.029)	(0.069)
Petion-ville	**-0.022**	**0.302*****
	(0.029)	(0.079)
Ponte-sonde	**-0.067**	**-0.286*****
	(0.054)	(0.061)
Medium Income	**0.061**	**0.114***
	(0.070)	(0.063)
High Income	**0.038**	**0.056**
	(0.077)	(0.058)
Constant	**2.138**	**5.690*****
	(2.298)	(1.240)
Observations	176	116
R^2	0.077	0.68
Note:	*p<0.1; **p<0.05; ***p<0.01	

3.1.2 Length and Width

As seen in Table 3, when observing the pooled models, length did not have a significant effect on price in any of the five models. In fact, length was not observed to significantly impact price in any model tested. This showed that Haitians do not care about the length of the rice, so long as it is perceived to be long grain rice. Every sample of rice that was collected was a long-grain variety, no matter the origin or the market. This showed a ubiquitous preference of

Haitians for long-grain rice over medium grain or short grain rice. Therefore, length clearly does matter to Haitians, as they all purchased long-grain rice, but it shows that once it is deemed long-grain, length is no longer a factor in their purchasing decision. To be considered long-grain, the rice length must be at least three times the width of the rice, which was the case in every sample of rice tested (Ricepedia).

In Table 3, width had a significant impact on price in models 2 and 3 with imported/domestic as the different variable. At $p < 0.1$, a .608% increase in price in model 2 and a .596% price increase in model 3 resulted from a 1% increase in width. Across all five models, it was observed that wider rice increased price, giving some significance to considering width in rice price in Haiti.

In Tables 4 – 6, categorizing the data by market, width was only to have significance ($p < 0.1$) in Table 6 when observing the Ouanaminthe market with imported/domestic and income also as variables. For increasing the price by 0.550%, width increased by 1% in this case, indicating that Haitians paid slightly more for a wider rice in Ouanaminthe when considering imported/domestic and income.

When divided by income brackets, width was seen to have a significant impact on high income consumers' price (Tables 7 -9). In Table 7, when only considering the quality attributes, a 1% increase in width resulted in a 1.140% increase in price for high income consumers ($p < 0.05$). Then in Table 8, when imported/domestic is taken into account, this increases to a 1.506% increase in price from a 1% increase in width with increased significance ($p < 0.01$). When location is then added in Table 9, it decreases to a 1.079% increase in price from a 1% increase in width with decreased significance ($p < 0.05$). This all shows that high income consumers tended to put more importance on wider rice than low income or medium income consumers.

Since width is generally considered a rice preference based on aesthetic, it makes sense that this would be a quality that would be only a concern to high income people.

In Table 10, when divided between imported and domestic rice, it appeared that domestic rice was priced 1.609% higher as a result of a 1% increase in width ($p < 0.01$). However, when imported/domestic then income were added in subsequent models (Tables 11 and 12), there was no longer significance observed for either domestic or imported for width's impact on price.

4. DISCUSSION

Haiti is a unique rice market given its high poverty rates yet it imposes some of the strictest quality standards for imported rice globally. These standards are importer and not government imposed which would suggest that this strict importation policy is not protectionism for the domestic rice industry which is characterized by low quality grains. Further this study and previous literature suggests that there is a strong revealed preference for domestic rice over imported rice in Haiti further questioning the presence of high importation quality standards. One possible explanation for importers wanting to delineate high quality imported rice from lower quality, yet higher priced domestic rice, could desire to ensure market segmentation. Of the findings of this study, the most robust is that consumers (across locations and income groups) are willing-to-pay less for a lower percentage of broken rice, with the exception of the highest income group. This should signal to policy makers in Haiti that consumers, specifically low-income consumers are willing to consume rice with a higher percentage of brokens. This is important from a food security standpoint as rice with a higher broken percentage can be sourced globally at a discounted price which, in turn, could help alleviate some food insecurity in Haiti

by providing a cheaper alternative to expensive domestic rice and imported rice which has an inflated price due to its high quality standards imposed by Haitian importers.

Across all samples the largest difference between brokens (max – min) resulted in a price difference of only 4.44%, a small amount given that price in the same samples ranged from $0.46/kg to $5.08/kg. Import standards mandate that imported rice is held to 4% broken or less, but there appears to be a failure in the supply chain because imported rice averaged 10.47% broken. This difference is likely due to handling and transportation once in Haiti. The result of brokens not driving price indicates one of two things. First, consumers can not differentiate between rice with varying levels of brokens. This could be the case if the level of brokens only marginally differed, but in our samples the range was over 40%. Given that rice is a staple in Haiti, it is unlike that Haitian's cannot differentiate the difference between a rice sample with 4% brokens (the import standard) and 40% broken. Second, and more likely, our results indicate that Haitian' specifically middle- and lower-class Haitians, don't have a large aversion to broken rice. This result, the main of this study, can have large implications for food security in Haiti as it suggests the import standard of 4 percent or less of brokens should likely be removed.

As of 2020, broken rice sold for 40% less than head rice, so that would mean that a 30% broken rice would sell for 11.36% less than a 5% broken rice. This price difference could allow the low-income population of people in Haiti to either eat more rice or eat the same amount of rice and increase their disposable income, both welfare gains. The results of this study are important because they strongly suggest that the current import structure is inefficiently feeding Haiti's low income population and selling a differentiated rice with increased broken percentage for a lower price has a place in the market.

The other important finding of this study is that Haitian's prefer Haitian rice regardless of quality. This has important implications for the Haitian rice industry as it struggles with production and quality issues. This finding, which runs parallel with previous studies, would suggest that money in the Haitian rice industry should be focused on increasing yield and area and not necessarily quality. In most markets, the opposite is true, where quality improvements are dictating industry growth. This result has strong implications for research and development in the agricultural sector in Haiti. Money should be increased to breeding for yield traits, research on best management practices and increased access to inputs over improvements in milling for quality attributes. While it is evident that Haiti will not be self-sufficient in rice production in the near future, the rice industry in Haiti should feel confident about its future given the high level of preference for local rice over imported higher quality rice.

This study also gives credence to American rice exporters who are trying to get lower quality rice into Haiti. Broken rice produced in the United States is often funneled off into the pet food industry at a substantial reduction in price by volume. If American broken rice can obtain better access to the Haitian market there is a possible Pareto gains. American rice producers would be better off as they would obtain a better price than what the pet food market provides and Haitian consumers would be better off as they would have access to cheaper rice (which it appears they are indifferent to, with regards to brokens). Haitian importers could be made better off too by segmenting the market by percent brokens and obtaining rents on each segment. Regardless, how the broken rice enters Haiti, it is evident that cheaper rice on the plates of the poor across Haiti is a better solution than in the bags of pet food.

In regard to other quality attributes, this study showed that length, width, discolored, and chalk are not generally significantly impacting the price of rice in Haiti. As discussed, all 300

samples purchased in Haiti were long grain rice, so length is important to Haitians, but just so long as it is long grain. Domestic Haitian rice was typically read as highly discolored, so there seems to not be a huge preference for the color of rice in Haiti, although all of the imported samples were white rice, with some being parboiled.

Further research should go to Haiti to develop an understanding of Haitian sensory preferences of rice. Sensory analysis is crucial to comprehending how brokens among other rice attributes affect the demand and subsequent price of rice to a particular culture. It would be interesting to see if Haitians would prefer domestic rice through sensory analysis as well as how they would perceive brokens.

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Chapter 3: Consumer Perception of Raw and Cooked Rice with Varying Levels of Percentage Broken Rice

ABSTRACT

Regardless of the level of sophistication of the rice mill, anywhere from 10% to 30% of the patty rice that is milled will be broken. Broken rice is sold at a significantly discounted price, resulting in massive losses to the rice industry. This is study aimed at understanding why that discount price persists and if the discounts perpetuated by rice marketing firms are aligned with consumers' willingness to purchase broken rice. In this experiment the percentage broken rice was the only independent variable (in incremental percentages of 5%, 10%, 20%, 30%, and 40%. Consumers who routinely consume rice, more than twice per month, where asked to evaluate raw and cooked rice with these varying levels of brokens. The results showed that the raw rice's appearance with high levels of brokens is disproportionately affecting the broken rice price. As seen through the ANOVA scores of hedonic and diagnostic mean responses for the cooked rice samples, the participants were not able to discern sensory differences as a result of tasting cooked rice with different broken percentages leading to the conclusion that cooked broken rice quality is not the main determinant in broken rice's significant discounts. In addition, results indicated that overall impression and overall texture were the two most significant determinants in willingness to purchase rice. Although increased raw broken rice was found to be inversely correlated with willingness to purchase, it was not as strong of an indicator as many of the cooked rice attributes.

1. INTRODUCTION

Broken rice (brokens) are defined as rice kernels that are less than 75% of the length of the whole kernel of rice (USDA, 2009). Because brokens are often perceived as having a "poor" appearance, rice with a high percentage of broken kernels demand a significantly lower price at retail. For example in 2020, broken rice sold at a discount of almost half, 41.9%, less than their whole kernel counterparts (USDA, 2020). Although some brokens are routinely mixed into whole rice at retail by unscrupulous retailers, brokens are mainly used for pet foods, breweries, skin creams, rice flours (ground brokens), and pastas, breads, and cereals extruded from rice flour (Bruce and Atungulu, 2018). Aside from being ground into flour for human consumption, brokens often go to uses that do not utilize their inherent nutrition. Despite being equally nutritious calories as full-length rice. It is the hypothesis of the authors that it is the appearance of the broken in raw rice that deters consumers rather than the brokens' sensory attributes after they have been cooked. Food choices, not just in rice, are a function of many interdependent environmental and personal reasons (Devine, 2005). The identification of food products that are nutrient rich and affordable should be prioritized in fighting the social inequalities that cause low-income consumers to purchase less healthy foods (Darmon and Drewnoski, 2015).

Rice kernels fracture mainly during the milling process as a result of internal fissuring typically originating during the drying process (Xangsayasane et al., 2019). Increased brokens can be a result of extent of milling, rapid moisture absorption, rapid drying, chalkiness, underdeveloped kernels, and environmental factors such as relative humidity, sudden temperature changes, or insect infestation (Siebenmorgen, et al., 1998). Modern rice mills generally generate between 10-15% brokens, whereas smaller, generally less modern mills can generate as much as 30% brokens (Muthayya et al. 2014). Understanding that brokens offer

significant lower return to the rice grower and processor than whole kernels, one can see why this is a vital economic concern for the rice industry worldwide. The less brokens they generate, the more whole kernel, head rice, produced and the higher profit margins become. However, many mills, often in underdeveloped countries, do not have the means or the technology to produce rice with low levels of brokens. Factors beyond milling such as quality of rice, storage and transportation conditions, and insects all play sizable roles in the amount of brokens produced as well.

Despite brokens being predominantly used in these various secondary ways, they do bring unique characteristics to cooked rice. Studies indicated that adjusting the ratio of broken kernels can influence the texture of the cooked rice (Saleh and Meullenet, 2013 and Park et al., 2001). Brokens have a higher fragmentation degree than whole kernels, meaning they have larger surface areas due to the area of the kernel that was internal being exposed once broken. This increases the capacity for water absorption, causing decreased hardness (Miles et al., 1985). Higher fragmentation in rice has also been found to increase the release of volatiles, affecting flavor (Wang et al., 2019). These unique attributes have caused broken rice to be seen as a delicacy in some cultures, such as Vietnam, Bangladesh, and Senegal, where consumers often are willing to pay a premium for broken rice (Dall, 2019). A higher degree of fragmentation also increased, under the same gelatinization temperature and cooking duration, the amount of starch to leach out, which created a more viscous texture in the cooked rice (Li and Gilbert, 2018).

Rice preferences vary among consumers based on flavor, aroma, texture, functionality, and appearance (Champagne et al., 2010). In addition, social and economic factors such as brand value, price, and place of origin all play a role in consumers' preferences in rice (Kim et al. 2017, Espejel et al., 2007). Although some eat rice as a side dish and prepare it simply with

water and salt, others want or need to eat it as a main dish, so they are inclined to flavor it with other aromatics, vegetables, and sauces (Crowhurst and Creed, 2003). In addition, the cooking methods of rice vary greatly depending on preferences and type of rice that is being cooked (Bett-Garber et al., 2007, Bhat and Riar, 2016). Optimal water to rice ratios (W/R) vary greatly based on previous research – anywhere from 0.8:1 parts of water to rice to 2.5:1 (Champagne et al. 1997; Zhou et al. 2002). Because of rice's generally bland flavor, the texture attributes of hardness to stickiness ratio have been found to be a strong indicator of overall acceptability (Srisawas and Jindal, 2007), not to say that other factors such as flavor, aroma, and appearance do not play an important role (Bairagi et al., 2019). These characteristics can also be measured analytically (Chung et al., 2011, Syafutri et al., 2016) and through a combination of sensory and analytical methods (Meullenet, 2000, Sesmat and Meullenet, 2001). It is clear that preferences, both personal and cultural, have an impact on brokens' perception to the rice consumer that does not have to be negative, despite a reduced cost.

To the authors' best knowledge, no prior studies have been conducted that test rice-eating consumers' (at least twice a month) perception of rice with varying levels of brokens both pre-cooking (raw) and post-cooking. While trained panels are useful in rice sensory analysis to determine specific factors and flavors, what drives purchasing decisions of consumers was the focus of this study, therefore untrained participants were used (Jung et al., 2001). By building on other sensory and market studies that observe how consumers perceive brokens, the objectives of this study were aimed at understanding if willingness to purchase (WTP) rice with increased levels of brokens was more a factor of appearance pre-purchase or sensory attributes post-cooking. The objective of this study was to determine at what level of brokens (if any) consumers can distinguish a noticeable difference in a variety of factors in raw and cooked rice.

By testing a wide range of percentage brokens (treatments of 5%, 10%, 20%, 30%, and 40%), we wanted to determine an inflection -point at which consumers can tell the difference between a standard 5% broken rice and increasing levels of brokens. Furthermore, if the percentage broken in the rice is discernible, does this affect the consumers' WTP? By testing subjects who routinely consume rice on their perception of the raw and cooked rice, we can learn how varying the levels of brokens affected various factors in the rice as well as at what point from pre-purchase to post-cooking is the consumer impacted by brokens. Through testing a variety of factors of each level of percentage broken, what factors into the consumers' WTP most significantly was learned.

2. MATERIALS AND METHODS

This study was conducted in accordance with the Declaration of Helsinki for studies on human subjects, and the protocol was approved by the Institutional Review Board of the University of Arkansas (Fayetteville, AR, USA). A written informed consent was obtained prior to their participation.

2.1 Participants

A total of 100 participants were recruited through the consumer profile database of the University of Arkansas Sensory Science Center (Fayetteville, AR, USA). The number of participant is within the accepted range established for consumer testing (Gacula and Rutenbeck, 2006). The screener was designed first and foremost to ensure the safety of the department, the participants, and the investigators during the COVID-19 Pandemic. Questions pertaining to the health, exposure, and travel of the participants ensured that health risks were minimized. The

screener asked questions concerning demographics, education, income, allergies, and health conditions. In addition, the screener ensured that the participants were considered rice-eating consumers, which was determined to be consuming rice at least two times per month. The study consisted of 77 females and 23 males aged from 19 years to 64 years (mean age ± standard deviation (SD) = 39.0 ± 11.8). The participants reported as 6 Asian, 10 Black, 7 Hispanic, 3 Other, and 74 White.

2.2 Samples and Preparation

In order to test participants' perception of uncooked and cooked rice with percentage broken being the only controlled variable, the investigators used the same five levels of brokens for each portion of the study. Rice was prepared in levels of 5%, 10%, 20%, 30%, and 40% in both cooked and raw forms. The control was deemed to be 5% as that is the generally accepted minimum a consumer would purchase at retail[7]. The rice was prepared in rice cookers (RC3314W Black & Decker) in intervals so that each cooked rice sample would be served to the group of participants at a consistent temperature of 70°C ±2°C, roughly five to seven minutes apart. In this way, all five participants per session were presented each of their rice samples at the same time as one another so that they were all roughly the same temperature/freshness. After the rice finished cooking, it was immediately fluffed with a fork and placed into the sample cups until the internal temperature was correct.

Optimum cooking duration (OCD) was measured by the Ranghino test for milled rice (Juliano and Bechtel, 1985). In a 250 mL beaker, about 100 mL of distilled water was boiled (98 ± 1°C) and five grams of rice samples were added. Measurement of cooking duration was

[7] Information gained through personal communication with rice industry executive

started immediately. After 10 minutes and every minute thereafter, 10 individual rice grains were removed and pressed between two clean glass plates. OCD was recorded when at least 90% of the grains no longer had opaque core or uncooked centers. The rice was then allowed to simmer for about another two minutes to ensure that the core of all grains had been gelatinized. The OCD including the additional two minutes of simmer was determined to be 24 minutes so that is what was used for this study, at a water-to-rice ratio of 2:1. Although there are more modern methods of determining OCD (Sinelli et al., 2006), this method is still accepted and widely used for its efficiency. Each of the five treatments of the uncooked rice samples were placed in transparent glass bowls to be presented to the participants. Five sets of two samples were presented to participants one after another in random order according to William's Latin Square. In each set of two samples, the control (5%) was labeled control with the test sample labeled with a three-digit code. The five tests were as follows: 1) control (5%) – test (5%), 2) control (5%) – test (10%), 3) control (5%) – test (20%), 4) control (5%) – test (30%), and 5) control (5%) – test (40%).

2.3 Procedure

In response to the COVID-19 pandemic, as participants arrived for the test, their temperatures were taken, they were instructed to wash their hands, and social distancing of six feet was enforced at all times between participants. Once in the sensory booth, the test began with the uncooked rice portion of the exam. Two samples, one labeled control and the other labeled with a three-digit code, were presented five separate times to the participants. They were asked to consider all aspects of the rice samples and indicate the size of the difference between the two samples on a 10-cm line scale with no difference on one end of the scale and extreme difference on the opposite end of the scale. This type of question is effective at quantitative

descriptive analysis to understand the degree at which difference is perceived (Yang and Boyle, 2016).

Following the five sets of uncooked samples, the cooked samples were presented each in a plastic cup with a white plastic spoon and a plain cracker and cup of water for palate cleansing. The cooked samples were randomly presented to the participants one after another with the only controllable difference being the level of brokens in the cooked rice. The same five levels used in the uncooked portion of the test (5%, 10%, 20%, 30%, and 40%) were used in this portion of the test.

For each rice treatment, a series of questions were asked of the participants before they could be presented with their next sample. First, the participants were instructed not to taste the rice sample before answering using a 9-point Hedonic scale from dislike extremely to like extremely their perception of the appearance of the rice sample. Then, they were instructed to sniff the rice sample and determine their liking/disliking using the same 9-point Hedonic scale of the overall aroma of the rice sample. Next, they were instructed to taste the sample and rate the rice flavor intensity, hardness (firmness), and stickiness using a 7-point JAR (Just About Right) Scale. They also rated using the same 9-point Hedonic scale the overall flavor, the texture (mouthfeel), and overall impression. Finally, the participants were asked to rate their willingness to purchase from extremely unlikely to purchase to extremely likely to purchase on a 9-point Hedonic scale.

2.4 Data Analysis

Using XLSTAT and JMP as data analysis tools after the data was collected and compiled in Excel, several forms of analysis were run using both platforms. Using Analysis of Variance

(ANOVA) tests, significant differences ($p < 0.05$) were observed through the mean responses using the Least Significance Difference (LSD) method. ANOVA analysis was used for hedonic and diagnostic means. Each question was broken down by percentage broken to understand how consumers responded by product.

Furthermore, in XLSTAT, penalty analysis was used to understand how answers to Just About Right (JAR) questions impact two variables of interest, willingness to purchase and overall impression. It determined how answers to JAR questions can have negative or positive impacts on the variables of interest. We used Penalty Analysis analyses both for the overall data and then used the amount of broken as a "By" variable, meaning the penalty analyses were carried out within each individual product.

Utilizing JMP, we created a table to observe the correlation comparisons that explain overall and by product which variables are correlated with one another. This table used "r" to understand the size of the correlation factor between any two variables and used p value to understand the correlation probability between any two variables, with $\alpha = 0.05$. This assumed Pearson correlation and non-normal distribution. Furthermore, a table was constructed as a way to count all of the responses for each level of percentage broken distributed by socioeconomic factors. Then, we completed two different regression model comparisons using Willingness to Purchase as the Y (response variable) and all of the other potential variables as the explanatory variables. We included one model that had all of the significant terms ($p<0.05$) which showed five significant variables in determining willingness to purchase. Then, a second model that was the "simplest" model contained only the top two variables with significantly stronger correlations to willingness to purchase than the rest of the variables.

3. RESULTS

3.1 Uncooked Rice

The results of this study showed that heavy rice-eating consumers could discern a greater difference in rice with increasingly higher percentage broken. An ANOVA analysis using the Least Significance Difference (LSD) method ($p < 0.05$) was used to compare the mean difference scores across the varying levels of brokens. Although the level of difference increases steadily from 5% (1.04), 10% (1.32), and 20% (1.67), these were all considered not significantly difference scores. At 30% broken, the score of 2.46 was significantly different than the scores of 5%, 10%, and 20%. 40% broken was seen as significantly different than 30% with a mean score of 3.45. This is seen in Figure 1. As the level of brokens increased in the uncooked rice, so did the participants' ratings on a 10 cm line scale from no difference to extreme difference, highlighting that participants could discern noticeable difference in uncooked rice as a result of increasing the percentage broken. However, in further analysis, the size of the difference in the raw rice did not have a strong correlation with willingness to purchase. As seen in Figure 14, size of the difference in the raw rice had a significantly positive correlation with responses for Firmness JAR for 20% broken and Stickiness JAR for 30%, and a significantly negative correlation with responses for Overall Aroma for 40%, Overall Texture for 20%, Overall Impression for 10%, and WTP for 10%.

3.2 Hedonic and Diagnostic Mean Scores for Cooked Rice

Using the LSD method of ANOVA analysis ($p < 0.05$), hedonic and diagnostic (JAR) questions were analyzed to determine the level of variance between responses of different broken percentages. Mean scores were compiled and compared for all six 9-point hedonic questions pertaining to the cooked rice and all three JAR questions. Out of the nine questions for cooked

rice samples, three questions (Overall Flavor, Overall Texture, and Flavor JAR) showed significant difference across the different levels of brokens. Figure 2 compared mean scores of these hedonic questions and Figure 4 compared mean scores of these diagnostic questions.

Across all hedonic questions, 30% broken scored higher than 10% and 20% except for Overall Appearance. Although not always a significant difference, this is noted because it was an unexpected trend observed across the data. Within the cooked rice portion of the study, three hedonic questions elicited significant difference – Overall Flavor, Overall Texture, and WTP. Although significant difference was observed in these three questions, none showed a consistent correlation with increasing percentage broken. 5% (the control) did score the highest in Overall Flavor, WTP, and tied for the highest score in Overall Texture with 30%. In regards to the diagnostic questions, significance was only observed in the Flavor JAR question. In the Flavor JAR question, 10% was significantly lower than 5%, 30%, and 40%.

Figures 13 and 14 showed the correlations between two variables of interest, WTP and Size Difference (Raw), respectively, with the other responses in the survey to gain an understanding of if WTP and Size Difference (Raw) were correlated with any other response on a product-by-product basis. Significance ($p < 0.05$) was found for correlations throughout the study; some variables were found to have a negative correlation with WTP and Size Difference (Raw) while others were found to have a positive correlation.

3.2 Penalty Analysis of JAR Questions

Using XLSTAT to observe the penalty analysis of the JAR questions, we observed how the responses to the JAR questions positively or negatively affected the responses to WTP and Overall Impression questions. First, as seen in Figure 3, the percentages of each JAR response was given based on a three-point JAR scale of Too Little – Just About Right – Too Much, which

is condensed from the original five-point JAR scale by aggregating categories 1 and 2 with each other as well as categories 4 and 5. 96% of participants reported too little for flavor, while respondents answered that the firmness and stickiness was too little 16% and 11%, respectively. Only 4% of participants thought the flavor was just about right, while 61% and 55% of respondents answered just about right for firmness and stickiness, respectively. While 0% of respondents answered too much for flavor, 23% participants responded with too much for firmness, and 34% participants responded with too much for stickiness.

Interestingly, a similar trend of penalties using this analysis both by product and across products for WTP and Overall Impression. Positive penalties (meaning the variables of interest, WTP and Overall Impression, were positively impacted by the non-JAR response) were observed for Stickiness and Firmness. These positive penalties were observed, both when respondents answered Too Much or Too Little for Firmness and Stickiness, but only when the respondents answered Too Much was significance ($p < 0.05$) observed. Flavor responses impacted WTP and Overall Impression drastically different, with negative penalties for Too Little and Too Much for Overall Impression and Too Little for WTP, with Too Much for WTP receiving a positive penalty. This discrepancy in penalties for Too Much can be understood as only 0.4% of respondents chose Too Much for flavor, so the sample size is too small to gather any further conclusions. These observations could be seen in Figures 5, 6, 7, and 8. Significance was shown in red bars and grey bars indicate that the size of the group is lower than the threshold needed.

In Figures 6 and 8, mean drops explained the difference between the means of the two non-JAR (Too Much and Too Little) categories and the JAR category. These figures displayed the mean drops as a function of the percentage of the participants who selected this category to

gain a better understanding of the real impact that each of the non-JAR categories had on the participants.

3.3 Regression Analysis

Using JMP, we ran a regression analysis to observe correlations and trends found in the data with respect to WTP. First, regression was observed with the top five significant variables in determining WTP. This can be seen in Figures 9 and 10. It showed that Overall Impression, Overall Texture, Gender, Income Demo, and Education were all significant in determining WTP. Overall impression was by far the most impactful with Overall Texture being the second most. WTP was predicted using this model of significant variables with an RMSE = 0.8202 and an $R^2$of = 0.85.

Next, as Overall Impression and Overall Texture were the two most impactful variables in determining WTP by a wide margin, we isolated these two variables in a regression analysis for WTP. Since these were both highly significant variables, running them in the model separately gave an understanding of their impact with no other variables playing a role in the regression for WTP. This resulted in a predictive model for WTP with an RMSE = 0.8457 and an R^2 = 0.83. These results showed that Overall Impression and Overall Texture were positively correlated with WTP. With only knowing how rice consumers perceive Overall Impression and Overall Texture, one can therefore reasonably predict their acceptance and subsequent WTP of the rice.

4. DISCUSSION

Because this study was a consumer-focused study (i.e. the participants were rice-eating-consumers and not trained panel), many of the points of analysis focused on WTP as a factor of consideration. Understanding why rice-eating consumers purchase the rice that they do was at the forefront of interest for the study - in particular, how brokens affected that purchasing decision. Testing respondents' impressions of raw rice provided insight as to how the consumer viewed rice pre-purchase. This study was then able to compare those same respondents' answers to questions about the cooked rice of the same levels of brokens to understand if the sentiments pre-purchase remained the same post-cooking.

Through observing consumers' changing perceptions of uncooked rice with varying levels of brokens, an empirical trend showed that consumers can visually discern increased difference as percentage broken in the rice samples increased (Figure 1). The more brokens in the rice sample, the greater the difference consumer could discern between the test and the control. This trend was seen at every level of increased brokens, with significance observed (p value < 0.05) between 20% and 30% and between 30% and 40%. The test used a 10-cm line scale which has been shown to be effective at quantifying the difference between two samples while giving the participant the ability to make a judgement on a continuous, less limited scale (Hootman, 1992). Given that a "0" at the far-left end of the scale would mean "No Difference" and a "10" at the far right end of the scale would mean "Extreme Difference", the average scores were relatively low across the treatments. The range of mean scores for the treatments was from 1.04 (5%) to 3.45 (40%), which shows that almost no difference was detectable in the 5% and a moderately low amount of difference was detected in the 40%. So, even at 40% broken, there

was not a huge amount of difference detected, which is understandable as all other controllable factors besides brokens were the same between the control and test.

The responses showing that consumers can tell the difference in increasing levels of brokens in rice then pointed to the question of whether the brokens were a factor in their purchasing decision. Across many cultures and rice-eating-populations, people tended to view brokens as of lower quality and prefer rice with lesser brokens (Custodio et al., 2019). In some cultures, such as Senegal, brokens could be perceived positively because of their unique cooking attributes or because of their association with certain (imported or domestic) rice which might be preferred (Demont et al., 2013). There was also a large population of rice-eating-consumers who were simply unaware of broken rice in their typical rice purchasing decisions (Mane et al., 2021). This test was conducted in Arkansas in the United States, where rice consumption per capita is relatively low at 10.8 kg per year (for reference, China eats the 15th most rice per capita at 125 kg per year) (Faostat, 2020). Because of the population tested, it was assumed that participants either had a negative connotation or no connotation concerning broken rice. This indicated that seeing increased levels of brokens in raw rice could have a negative impact on consumers' WTP, as this trend was consistent across all samples (Figure 14).

It was apparent through this study that consumers could tell the difference between rice samples with different levels of brokens. As seen in Figure 13, increasing Size Difference (Raw) had a negative correlation with Overall Impression and WTP across all treatments, although significance was not found in every treatment. This points to a conclusion of increasing size difference in raw rice having a negative impact on the WTP and Overall Impression of the cooked rice. Size Difference (Raw) had a majority negative correlation across treatments for all other variables, except Firmness and Stickiness, which showed that lower levels of brokens had a

positive correlation with increased Firmness and higher levels of brokens had a positive correlation with Stickiness. This was understandable as increased percentage broken generally makes rice less firm and stickier (Saleh and Meullenet, 2013). Knowledgeable consumers could then use this information when prioritizing the level of brokens in their rice.

This knowledge is coupled with the extensive questions throughout the rest of the study that pointed to the participants' general lack of awareness of varying levels of brokens in the samples. As seen in Figure 2, there was never linearity throughout the increasing levels of brokens, no matter which response was being evaluated. In every hedonic question, 5% was rated higher than 40%, but there was not significance throughout. Figure 4 showed that there was no significance in any of the diagnostic questions, but it does show a trend that Firmness slightly decreased as percentage broken increased and Stickiness slightly increased as percentage broken increased. This led to an understanding that increased brokens creates rice that kernels were more cohesive and less individual kernels, which could be desirable or undesirable depending on preference and recipe. Overall, the hedonic responses showed that there was a relatively small difference in perception between 5% and 40% broken compared to the massive difference in brokens. This discrepancy in perception is not in line with the relative cost difference. Brokens are often sold at significant discounts (almost 42% in 2020) (USDA, 2020) because they go to uses that are not meant for direct human consumption (Dias et al., 2010) despite them being equally as nutritious and not significantly different in sensory perception from head rice as seen in this study.

In Figure 3, the JAR scale was collapsed into Too Much, Just About Right, and Too Little for the pertaining JAR questions with total respondents (out of 100) listed for each of the three categories to give an understanding of the total picture of responses for the JAR questions.

96% of participants rated Flavor as Too Little, which is because there was no salt in the rice samples, leading to a bland flavor in rice. We also observed that more respondents rated the rice samples as too sticky (34) than too firm (23), and more respondents rated the rice samples as not firm enough (16) than not sticky enough (11). This indicated that overall the rice samples tended to be perceived as stickier rather than firmer. This could have been because rice samples were not rinsed before use or because the participants were accustomed to eating less sticky rice, such as parboiled rice (Li and Gilbert, 2018).

These percentages of diagnostic responses were extrapolated in Figures 6 and 8 and were important to consider in Figures 5 and 7. These figures looked at the Penalty Analysis performed which considered how these JAR scores impacted two variables of interest, Overall Impression and WTP. This analysis was run by product and across all products, and the same trend was seen across each of the test, aside from Much Too Strong in Flavor, which can be explained from a very small sample size (Hertzog, 2008). The trend observed was that when the JAR scores were Too Much or Too Little for Stickiness and Firmness, there was a positive impact on Overall Impression and WTP. Throwing out Too Much for Flavor because of small sample size, Too Little for Flavor had a negative impact on Overall Impression and WTP. Since 96% of participants rated the Flavor as Too Little and there were on average low Overall Impression and WTP ratings across samples, the negative impact was understood. Regardless of if Too Little or Too Firm, the mechanism by which Stickiness and Firmness ratings had a positive impact on Overall Impression and WTP was not known. However, only when the ratings were Too Sticky or Too Firm was there significance observed. It is a consistent trend across samples, so it was worth noting for future consideration.

In Figures 9 and 10, regression analysis was performed to understand which terms affected WTP the most, with significance found for five variables (in descending order of significance): Overall Impression, Overall Texture, Gender, Income Demo, Education. WTP was predicted by significant terms with an RMSE = 0.8202 and R^2 of = 0.85 showing that these terms could predict the respondents' WTP by roughly 85% with roughly 82% of answers following a normal distribution. This indicated that these five variables were the most important to consider in analyzing WTP for rice, regardless of the percentage broken. Figures 11 and 12 focused on the two most important factors, Overall Impression and Overall Texture, to create a regression for WTP with an RMSE = 0.8457 and a R^2 = 0.83. This showed that only using Overall Impression and Overall Texture, WTP could reasonably be predicted. Overall Impression was the strongest indicator of WTP because Overall Impression is the most encompassing factor that was asked, so it was natural that it had a strong correlation with WTP. The higher the participant's Overall Impression correlated with a higher WTP, showing that Overall Impression is an adequate predictor for rice consumers' WTP.

Size Difference (Raw) having a negative correlation with WTP corroborated with the conclusion of brokens in uncooked rice having a disproportionately negative impact on rice-eating-consumers' WTP. To better understand this conclusion, consider in this scenario that brokens are sold from manufacturer to retailer at a 40% discount and whole rice is sold at \$4.00/kg: Rice A is 5% broken and sold at \$3.92, whereas Rice B is 40% broken and sold at \$3.36. That is a \$0.56/kg increase or a 14.29% increase in price from Rice B to Rice A for that retailer. That retailer would have to sell the Rice A at a considerably higher price (at least 14.29% higher) in order to make the same profit as Rice B, which is a lot of money when dealing with rice in terms of shiploads. But, according to this study, it appeared that the average rice-

eating consumer could only decipher a small, sometimes negligible, difference between the two. If reasonable consumers would pay less for a product of perceived equal value, why would the supplier not want to sell the 40% broken rice at a higher price? This is because of the perceived difference in the rice as seen in the first part of the study with the raw rice.

5. CONCLUSION

This study added to a growing interest and understanding of how broken rice factors into all aspects of the supply chain, from farm to manufacturer to retail to consumer. Brokens, being sold at significant discounts of 20% to 40% from suppliers, are cheaper to retailers and consumers because of their perceived "poor" appearance. The discounts are not because of their poor quality attributes in cooked rice, as this study (among others) has shown that many rice-eating-consumers had a difficult time discerning differences in rice of different percentage broken, especially if it is only a small percentage difference. Rice is purchased as a raw product, therefore it is essential that in its raw form it is perceived positively, despite if negligible difference can be observed in its cooked form. In conclusion, if consumers are not highly concerned with the appearance of their raw rice, then they should want discounted rice with increased broken percentage. WTP was affected by cooked rice factors, especially seen in Figure 13 where many factors, some significant, had a positive impact on WTP. Overall Impression and Overall Texture, as seen in Figure 12, highlighted this.

The findings of this study, including the empirical trend of rice that is too sticky or too firm having a positive impact on WTP and Overall Impression, should be considered in further studies to better understand the purchasing behavior of rice consumers. Better understanding of why brokens' poor appearance in their raw form play such a profound role on price despite

consumers' impression of brokens in cooked rice not having a strong impact on perception is warranted. Trained panels could be used in future studies to increase specific knowledge on how the same sample of broken rice in its raw and cooked forms are perceived. Finally, further studies should seek to understand the break-point of acceptance (both raw and cooked) for brokens with less variation, as this study had a wide range of 5% - 40%.

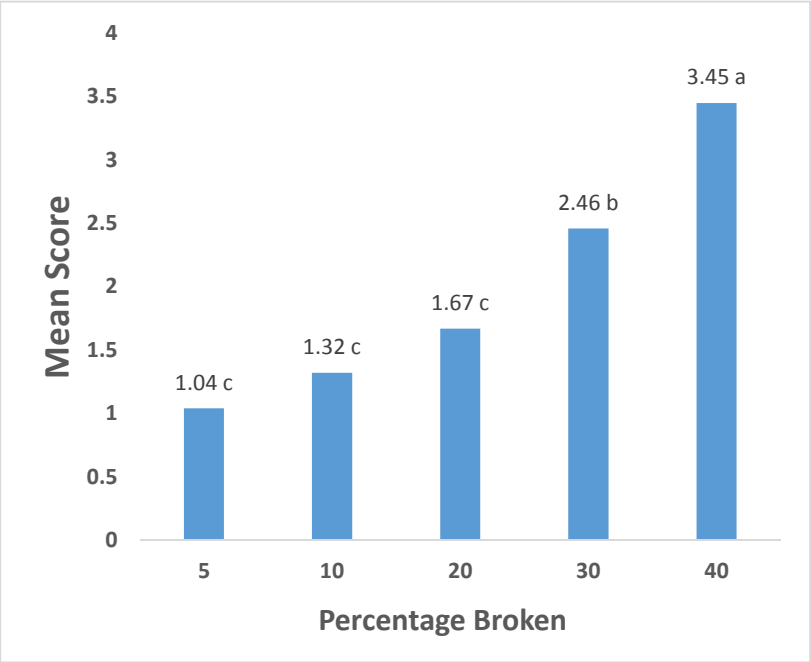

Figure 9: Uncooked Difference Mean Scores

Means with the different letters for each attribute are significantly different ($p<0.05$) using the Least Significance Difference method.

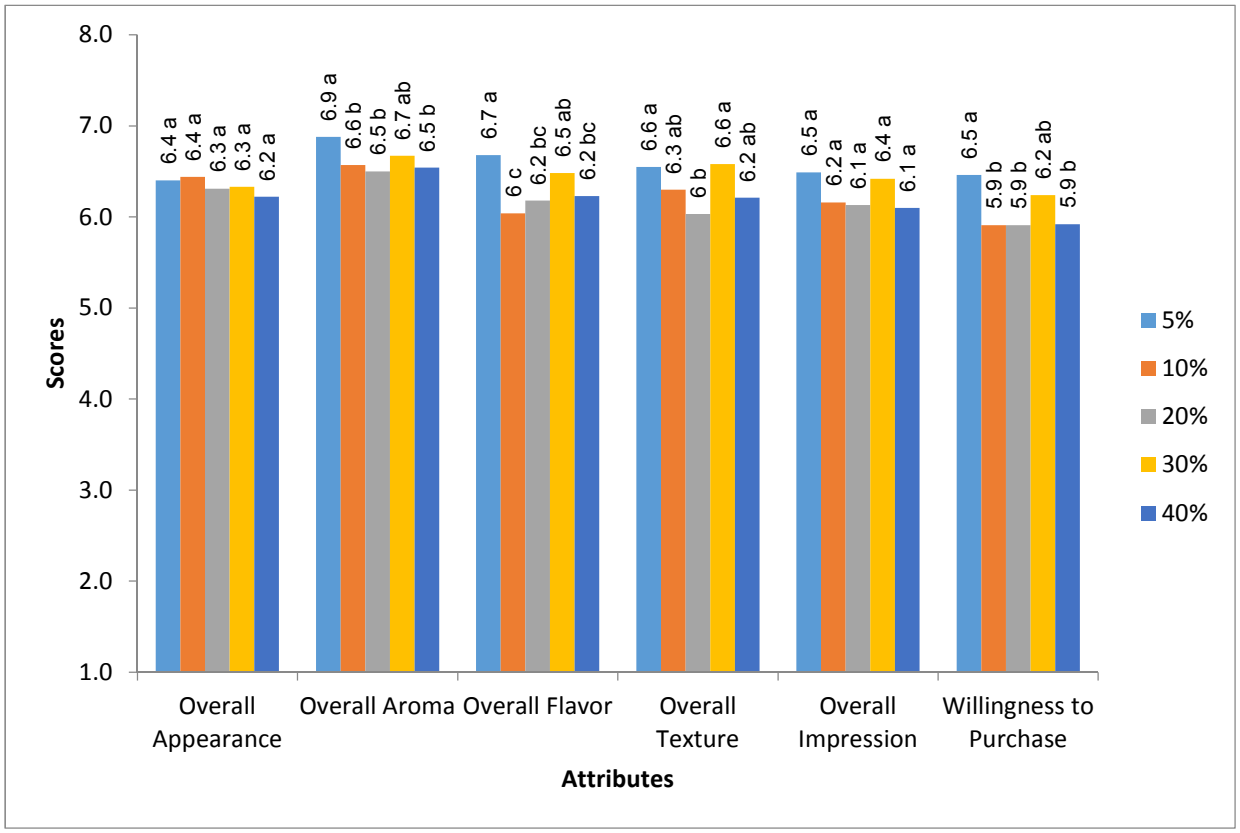

Figure 2: Mean Scores of Hedonic Questions

Means with the different letters for each attribute are significantly different ($p<0.05$) using the Least Significance Difference method.

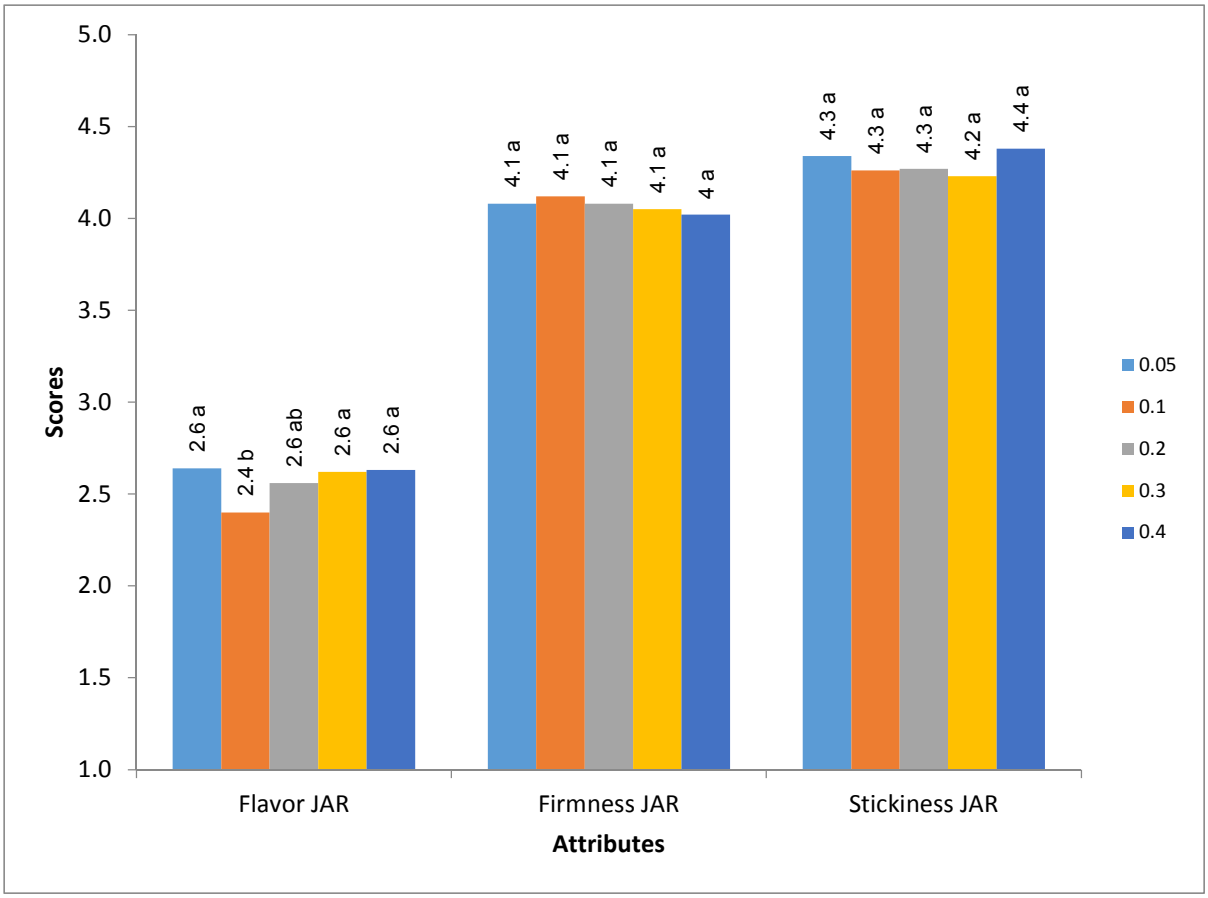

Figure 3: Mean Scores of JAR Questions

Means with the different letters for each attribute are significantly different ($p<0.05$) using the Least Significance Difference method.

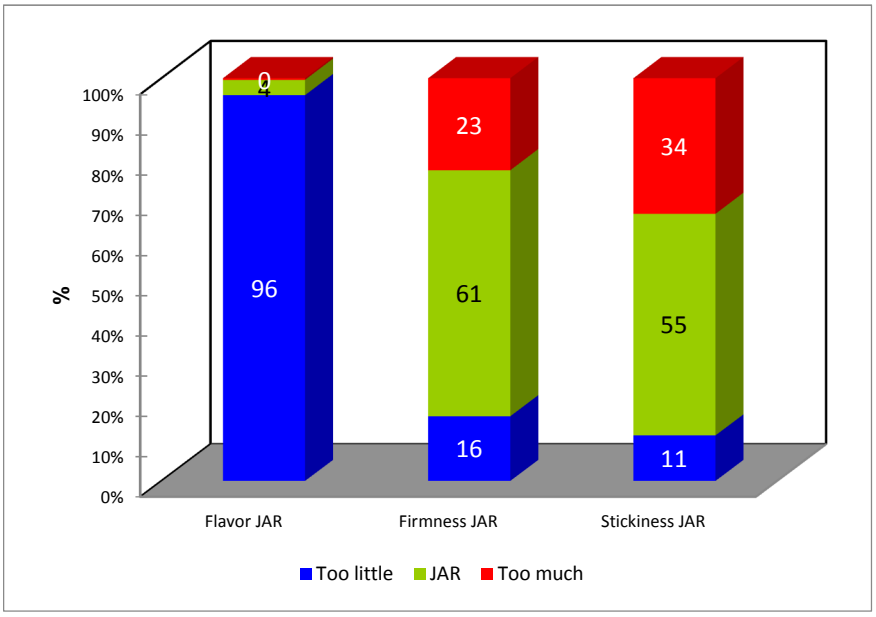

Figure 4: Percentages for the JAR Levels (collapsed)

The original JAR scale was collapsed into a 3-point

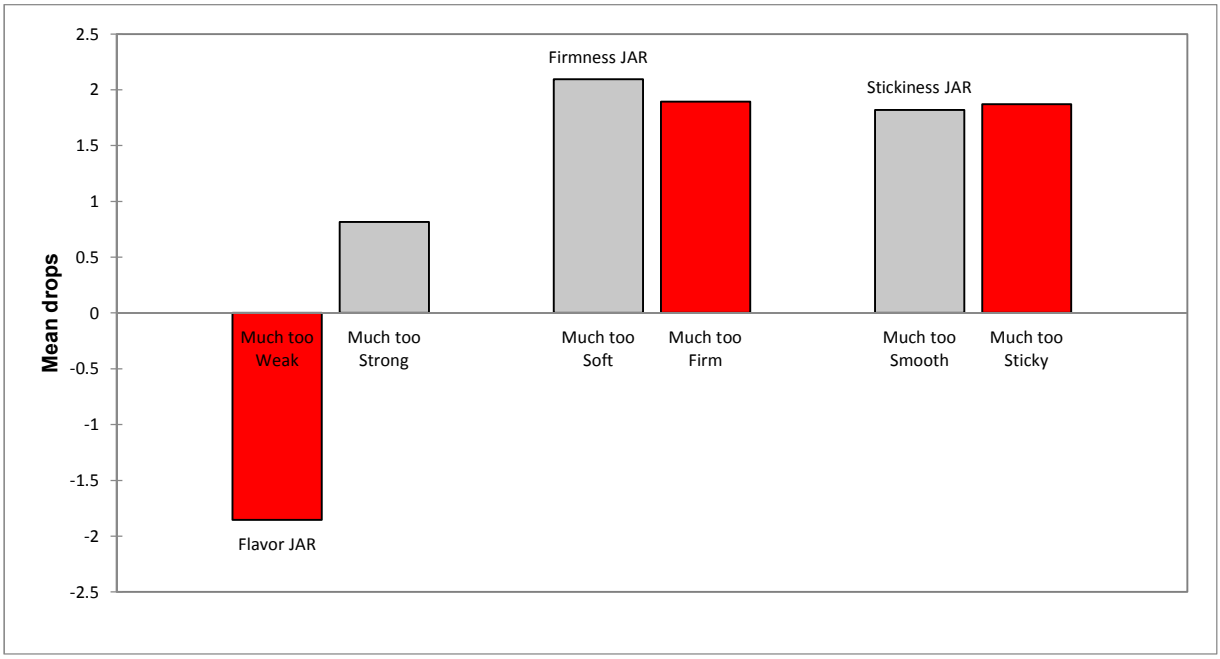

Figure 5: Mean Penalties for Willingness to Purchase (WTP)

Mean drops vs %:

Variable	Level	%	Mean drops
Flavor JAR	Much too Weak	95.800	-1.853
	Much too Strong	0.400	0.816
Firmness JAR	Much too Soft	16.200	2.094
	Much too Firm	22.800	1.894
Stickiness JAR	Much too Smooth	11.400	1.818
	Much too Sticky	33.600	1.870

Figure 6: Mean WTP Penalties vs. Percentage JAR Level

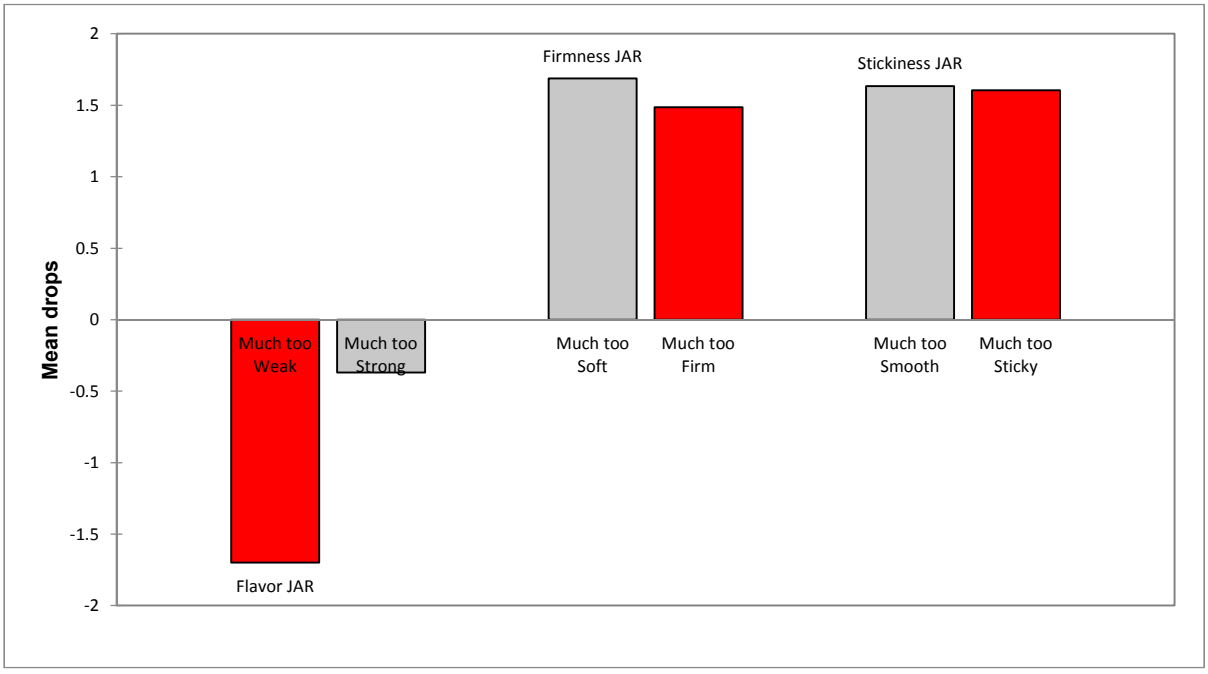

Figure 710: Mean Penalties for Overall Liking

Mean drops vs %:

Variable	Level	%	Mean drops
Flavor JAR	Much too Weak	95.800	-1.698
	Much too Strong	0.400	-0.368
Firmness JAR	Much too Soft	16.200	1.687
	Much too Firm	22.800	1.486
Stickiness JAR	Much too Smooth	11.400	1.635
	Much too Sticky	33.600	1.605

Figure 811: Mean Penalties for Overall Liking vs. Percentage JAR Level

Source	LogWorth	PValue
Overall Impression	81.265	0.00000
Overall Texture	4.198	0.00006
Gender	2.393	0.00404
Income Demo	2.035	0.00922
Education	1.377	0.04199

Figure 9: WTP Regression with Significant Terms

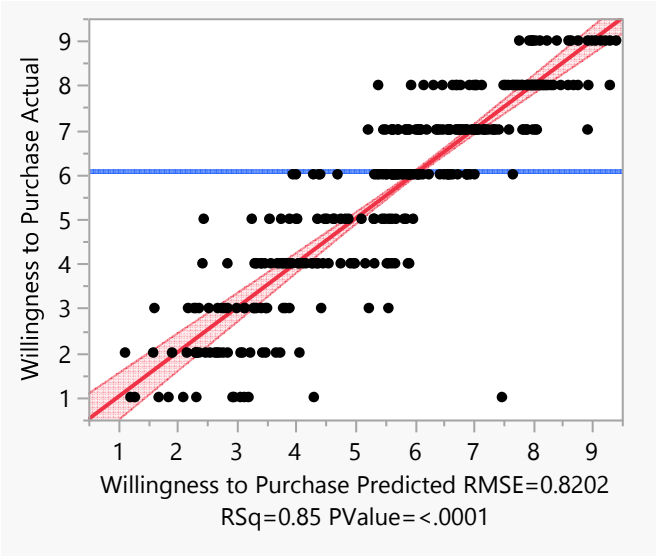

Figure 10: WTP Response Predicted by Significant Terms

Source	LogWorth	PValue
Overall Impression	79.031	0.00000
Overall Texture	5.333	0.00000

Figure 11: WTP Regression with Overall Texture and Impression

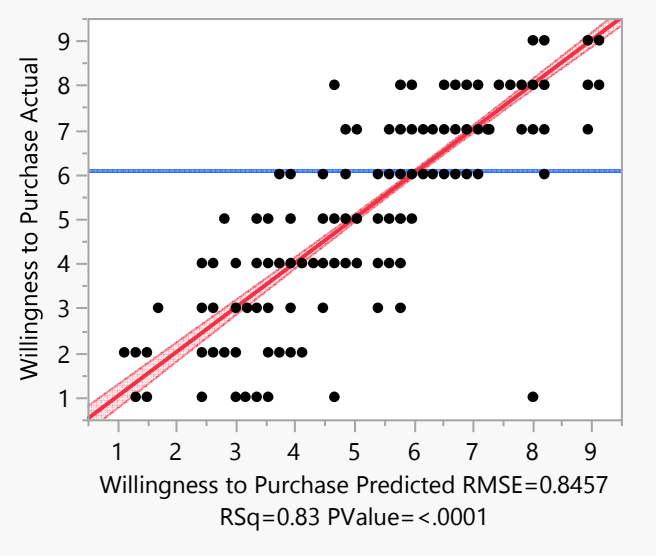

Figure 12: WTP Response Predicted by Overall Texture and Overall Impression

	Size Difference (Raw)				
	5%	10%	20%	30%	40%
Overall Appearance	-0.06	-0.04	-0.12	-0.17	-0.15
Overall Aroma	-0.08	-0.13	-0.11	-0.07	-0.21
Flavor JAR	0.11	-0.09	-0.01	0.05	-0.14
Overall Flavor	-0.02	-0.11	0.02	0.02	-0.19
Firmness JAR	0.12	0.08	0.29	-0.09	0.05
Stickiness JAR	-0.08	-0.05	0.02	0.21	0.07
Overall Texture	-0.09	-0.12	-0.21	0	-0.11
Overall Impression	-0.03	-0.21	-0.11	-0.02	-0.15
Willingness to Purchase	-0.03	-0.23	-0.08	-0.04	-0.1
Size Difference (Raw)	1	1	1	1	1

Figure 13: Size Difference (Raw) Correlations

Correlations shaded in green are significant (p value < 0.05), correlations in red are negative, correlations in blue are positive.

	Willingness to Purchase				
	5%	10%	20%	30%	40%
Overall Appearance	0.63	0.49	0.54	0.7	0.6
Overall Aroma	0.47	0.44	0.38	0.52	0.44
Flavor JAR	0.1	0.33	0.29	0.32	0.2
Overall Flavor	0.67	0.7	0.69	0.77	0.75
Firmness JAR	0.05	-0.13	0.03	-0.15	0.14
Stickiness JAR	-0.2	0.01	-0.39	-0.17	-0.31
Overall Texture	0.72	0.76	0.82	0.9	0.82
Overall Impression	0.9	0.9	0.91	0.93	0.89
Willingness to Purchase	1	1	1	1	1
Size Difference (Raw)	-0.04	-0.23	-0.09	-0.04	-0.09

Figure 14: Willingness to Purchase Correlations

Correlations shaded in green are significant (p value < 0.05), correlations in red are negative, correlations in blue are positive.

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Chapter 4: Conclusion

Although different in focus, scope, and demographic, the two studies conducted in this research worked hand-in-hand to bring light to something larger that is happening in the world. With a current population of 7.87 billion people, 690 million people (8.9%) are undernourished or go to bed hungry every night (World Vision, 2021). The world population is projected to reach 10 billion by 2056, and the problem of hunger is only on the rise (ourworldindata.org). This is not a problem that has one solution or one food that is going to be the savior. It will be a collective effort of innovators to either find new value in existing foods or find new means of processing foods in order to feed this growing population. Broken rice could be a solution in the former.

Broken rice is an inevitability in rice production, with out-of-date mills (many in low-income areas) producing significantly more broken rice than modern mills. By weight, this can result in up to 30% of the rice yield being broken. This can be seen clearly in Haiti, a nation that is the poorest in the Western hemisphere and relies on rice for 30% of their daily calories. Despite rice produced in Haiti being heavily broken, domestic rice in Haiti is priced at a premium as a result of consumer preference for buying domestically and the rice producers in Haiti not being able to capitalize on economies of scale in order to lower their costs. This has caused imported rice to be increasingly important to Haitians, especially those lacking in calorie fulfilment. As we found, this imported rice is not highly differentiated in terms of brokens, with strict broken standards imposed by importers resulting in a very low percentage broken in the imported rice (roughly 5%). Having such low amounts of brokens in the rice, the cost of the rice would inevitably increase. This is why we sought to understand if a discounted rice with a higher broken percentage would be desirable for the poorest of the poor in Haiti.

We found that the amount that Haitians discount brokens in their rice preferences does not nearly match with the actual discount that would exist with increased brokens, with brokens costing 40% less than their whole kernel counterparts in 2020 (USDA, 2020). This means that a more broken imported rice product could have a strong place in the Haitian market for the very poor. With Haiti as a nation of interest but world hunger as the larger scope, this research saw an effective solution as to how a natural by-product of rice production could be used to feed hungry people as opposed to going to uses that do not feed people.

In order to gain a more full understanding of why brokens are so highly discounted, a sensory study was performed to test rice-eating consumers' perceptions of broken rice in the raw and cooked forms. The sensory study performed, although in Arkansas and not Haiti, did provide useful insight into how consumers perceive brokens. Brokens' "poor" appearance in the raw form appeared to be the main cause for the heavy discounts, as consumers could not tell a significant difference most of the time with increased levels of brokens in their cooked rice. We know that brokens are discounted for a reason because if a rice producer could sell the brokens at the same price, they logically would. The question then persists of what this cause could be, and based on this research, it appeared that brokens were inversely correlated with willingness to purchase, but not by a significant amount. This further backs up the findings in Haiti that brokens are a cause of a discount in consumers' willingness to purchase rice, but it is disproportionate to the discounts for brokens that exist.

In light of this, what would be logical next steps? While brokens are as discounted as they are, there should be increased differentiation in rice brands with high levels of brokens at a fraction of the cost. Prove to the consumer that the final cooked rice product is not significantly deterred, then their choice would be easy – buy the cheaper option. This is especially true for

those who would be priced out of the more expensive, less broken option. Utilizing sensory and market analysis gave true insight into an aspect of the most important crop in the world that is not being used to its maximal potential. If the goal is to feed an increasingly growing population of hungry people, solutions such as these should be pursued by ethical rice producers. In fact, there would still probably be better margins in selling a rice blended with brokens than selling the brokens wholesale to a pet food company or brewery.

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Appendix

The following is the questionnaire asked to roughly 300 Haitians between the four major markets in Haiti. Rice samples from those asked the questionnaire were collected and sent back to the Food Science lab at the University of Arkansas for analysis.

1. How much did you pay for the rice you just bought? _____ per _____
2. Do you usually buy the rice in sealed bags / open bags[8]?
   a. Why? Rank main reasons 1 - 3, with 1 being the most important to you and 3 being the least.

      _____ Brand Trust

      _____ Quality

      _____ Origin
3. How much rice does your household eat on average?: _____ per _____
4. Do you know the variety of the rice that you purchased? Yes _____ No ___
   a. If yes, what is it? _____
5. Do you know the brand of the rice that you purchased? Yes _____ No ___
   a. If yes, what is it? _____
6. Do you know whether the rice you consume is domestic or imported? Yes ____ No ____
   a. If yes, do you prefer imported or domestic rice? Imported ____ Domestic ____
7. Did you come to buy a specific variety today? Yes _____ No _____ And was it the variety that you purchased? Yes _____ No _____
   - If no, why not?

     _____

[8] Circle the one that applies based on the rice bought by the respondent.

8. How do you choose the rice you buy? Rank reasons 1 - 5, with 1 being the most important to you and 5 being the least. You do not need to include all of the options in your ranking.
    a. _____ Cleanliness
    b. _____ Price
    c. _____ Amount of broken rice
    d. _____ Amount of chalk
    e. _____ Brand
    f. _____ Origin
    g. _____ Color
    h. _____ Money on hand
    i. _____ Other

9. Do you usually clean/wash the rice before cooking? Yes _____ No _____
    a. If yes, Why? (e.g., to remove foreign matters, to remove chalk rice, to wash dirt)
        - _____
        - _____
        - _____

10. Gender: _____

11. Age: _____

12. Your household size: _____

13. What is the highest education level you have completed?
    a. None
    b. Primary school
    c. Began secondary school
    d. Finished Secondary School (Philo)
    e. Began University
    f. University "Finishing Student"
    g. University graduate

h. Graduate

14. What is your average household income? _____ per _____ (example, for every week, month, harvest, or year) If by harvest, how many harvests per year? _____

15. Have you changed your purchasing decisions based on the recent COVID-19 Pandemic? Yes _____ No _____

    a. If yes, have you purchased more or less rice than usual? _____

16. During the COVID-19 Pandemic, have you seen the local prices of rice increase, decrease, or stay the same? _____

The following is the Approval letter from IRB.

UNIVERSITY OF ARKANSAS

To:	Philip G Crandall FDSC N-213
From:	Douglas James Adams, Chair IRB Expedited Review
Date:	06/22/2020
Action:	**Exemption Granted**
Action Date:	06/22/2020
Protocol #:	2005265358
Study Title:	Optimizing Rice Preferences in Regards to Broken Rice and Culture

The above-referenced protocol has been determined to be exempt.

If you wish to make any modifications in the approved protocol that may affect the level of risk to your participants, you must seek approval prior to implementing those changes. All modifications must provide sufficient detail to assess the impact of the change.

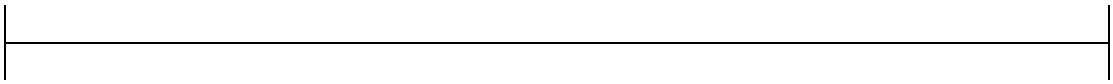
If you have any questions or need any assistance from the IRB, please contact the IRB Coordinator at 109 MLKG Building, 5-2208, or irb@uark.edu.

cc: Han-Seok Seo, Investigator
Matthew G Richardson, Investigator

The following is the protocol followed for the sensory study portion of this project. This was carried out after being approved by IRB with participants that were chosen based on their responses to the survey above.

Sensory Evaluation of Raw Rice Grains

You have received two samples, a control sample labeled "Control" and a test sample labeled with a three-digit code. Please compare the test sample with the control sample. When considering all aspects of rice samples, please indicate the size of the difference between the two samples on the scale below. Please remember that a duplicate control is the sample some of the test time.



No difference Extreme difference

** This is a 10-cm line scale.

** This question will be asked to five times: 1) control (5%) – test (5%), 2) control (5%) – test (10%), 3) control (5%) – test (20%), 4) control (5%) – test (30%), and 5) control (5%) – test (40%) and these will be randomized (according to William's Latin Square)

** Raw rice samples will be presented in a transparent glass bowls.

** Please let us know if panelists will be allowed to smell and/or touch raw rice samples. Because of the COVID-19, I don't recommend it.

Sensory Evaluation of Cooked Rice

Instruction: You are going to receive five cooked rice samples one after another. For each sample, please look at, sniff, and taste the sample and answer the following questions. Please use a white plastic spoon when you consume rice samples. You don't need to consume an entire rice sample. Between the rice sample presentations, there will be a 3-min break. During the break, please clean and rinse your palate using water given.

Please do not taste the rice sample yet. Please look at the sample and answer the question.

Appearance:

Q1) How much do you like or dislike APPEARANCE of the cooked rice sample?

□	□	□	□	□	□	□	□	□
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Please sniff the rice sample and answer the questions.

Aroma:

Q2) How much do you like or dislike OVERLL AROMA of the cooked rice sample?

□	□	□	□	□	□	□	□	□
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Please taste the rice sample and answer the questions.

Flavor:

Q3) Please rate the level of RICE FLAVOR INTENSITY of the cooked rice sample?

□	□	□	□	□	□	□
Much Too Little	Too Little	Slightly Too Little	Just-About-Right	Slightly Too Much	Too Much	Much Too Much

Q4) How much do you like or dislike OVERLL FLAVOR of the cooked rice sample?

□	□	□	□	□	□	□	□	□
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Texture:

Q5) Please rate the level of HARDNESS (FIRMNESS) of the cooked rice sample?

□	□	□	□	□	□	□
Much Too Little	Too Little	Slightly Too Little	Just-About-Right	Slightly Too Much	Too Much	Much Too Much

Q6) Please rate the level of STICKINESS of the cooked rice sample?

□	□	□	□	□	□	□
Much Too Little	Too Little	Slightly Too Little	Just-About-Right	Slightly Too Much	Too Much	Much Too Much

Q7) How much do you like or dislike TEXTURE (MOUTHFEEL) of the cooked rice sample?

□	□	□	□	□	□	□	□	□
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Overall Impression:

Q8) When considering all aspects, how much do you like or dislike the cooked rice sample?

□	□	□	□	□	□	□	□	□
Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neither like nor dislike	Like slightly	Like moderately	Like very much	Like extremely

Willingness to purchase:

Q9) How likely would you purchase the cooked rice sample?

□	□	□	□	□	□	□	□	□
Extremely unlikely	Very unlikely	Moderately unlikely	Slightly unlikely	Neither likely nor unlikely	Slightly likely	Moderately likely	Very likely	Extremely likely

The following is the Informed Consent letter sent to all potential participants in the Sensory Service Center. This gave the participants full knowledge of the study and the IRB approval of it.

INFORMED CONSENT

Title: Cultural Preferences: Optimization of Rice

Researcher(s):

Phil Crandall, Ph.D., Faculty

Matt Richardson, Graduate student

University of Arkansas, CAFLS

Department of Food Science

2650 N. Young Avenue

Fayetteville, AR 72704

Crandal@uark.edu (Crandall);
mgr001@uark.edu (Richardson)

Administrator:

Ro Windwalker, CIP
IRB Coordinator
Office of Research Compliance
109 MLKG Building
University of Arkansas
Fayetteville, AR 72701
479-575-2208
irb@uark.edu

Description: This study aims to examine consumer sensory perception of rice samples, both cooked and uncooked. You should not have the following things: 1) clinical history of major diseases (e.g., cancer, cardiovascular disease, diabetes, etc.), 2) impairments of smell, taste, sight, hearing, or touch, and 3) food allergy or intolerance. In this study, you will be asked to taste and evaluate samples in terms of their sensory characteristics (appearance, aroma, flavor, taste, and textural characteristics). You will be asked to refrain from smoking, eating, and drinking for 2 hours prior to your participation; drinking water is allowed. It will take about 30 to 50 minutes to complete the test.

Risks and Benefits: All food samples presented in this study are prepared with commercially available ingredients or products. However, if you have known allergies or intolerances for specific odors, please describe them here:

_____.

U.S. adult citizens: After completing this study, you will receive a Walmart gift card ($20) as panel reward.

Voluntary Participation: Your participation in the research is voluntary. The voluntary participation, i.e., choosing to participate or not, will have no effect on your relationship with the researchers or the University in any way.

Confidentiality: Your information on identity (e.g., name) will be coded as a number (e.g., 1, 2, 3, etc.). The code number will be matched with your responses; that is, your data will be recorded anonymously. All information will be kept confidential to the extent allowed by law and University policy. Results from the research will be reported as aggregate data.

Right to Withdraw: You are free to refuse to participate in the research and to withdraw from this study at any time. Your decision to withdraw will bring no negative consequences — no penalty to you.

Informed Consent*:* I, _____ (please print), have read the description, including the purpose of the study, the procedures to be used, the potential risks, the confidentiality, as well as the option to withdraw from the study at any time. Each of these items has been explained to me by the investigator. The investigator has answered all of my questions regarding the study, and I believe I understand what is involved. My signature below indicates that I freely agree to participate in this study and that I have received a copy of this agreement from the investigator.

_____

Signature **Date**

If you have questions or concerns about this study, please contact one of the researchers listed above. For questions or concerns about your rights as a research participant, please contact the University's IRB Coordinator listed as "Administrator" above.