5-2023

Potential Control of Invasive Mesquite Through Improving the Consumer's Understanding of Liquid Smoke Applications.

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Potential Control of Invasive Mesquite Through Improving the Consumer’s Understanding of Liquid Smoke Applications.

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Food Science

by

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Brigham Young University
Bachelor of Science in Food Science, 2015

May 2023
University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

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Abstract

Mesquite trees continue to invade forests and range lands in many countries across the world. The cost to remove these trees is staggering. In Texas, landowners spent $25 million over a 10-year period to clear 300,000 ha of mesquite trees, a fraction of the 22 million ha of Texas land affected by this invasion. Estimates are that the mesquite continues to negatively impact one to two percent of additional land in selected counties each year in Texas. However, the problem is not unique to Texas, but rather to the 44 species of mesquite trees, belonging to the genus *Prosopis* found in the pea family, the *Fabaceae*, introduced across the southern United States, South Asia, Africa, the Middle East, South America, and the Caribbean. In response, researchers are searching for economically viable uses for harvested trees and seeds to provide an alternative to the high cost of removal. If viable uses for harvested mesquite trees and seeds are found, then sustained pressure will limit and ultimately reduce the negative impact from these invasive trees. One key factor to controlling this invasive species is to find economically and environmentally sustainable uses to help pay the costs of removal or perhaps make removal less necessary. Traditional uses of mesquite are as a building material, as a source of food for both animals and humans and as wood for charcoal. Emerging uses of mesquite are new applications as a biofuel and as a bio-filter medium for water. Moreover, forestry land management of mesquite has adapted to include the tree as a component of hunting lands. New control methodologies and technologies are based on an increased understanding of mesquite growth patterns, using recommended practices that reduce control and eradication costs while improving the efficiency of land management. Previous land management practices have proven that excessive application of herbicides, physical removal of mesquite trees, or human-induced brush fires, if not carefully planned, only worsen mesquite infestations. The growing problem of mesquite land management provides an opportunity for continued research into novel ways to utilize mesquite biomass, of both wood and seed pods. For example, liquid smoke application for poultry products. Boneless, skinless chicken breasts comprise almost 30% of total poultry sales and poultry remains US consumers' protein of choice. This research sought to determine whether consumers of chicken would pay a premium for a smoked chicken breast that was healthier and produced with less of a negative impact on the environment. Two balanced consumer panel groups were presented with information on the two value prospects of smoked chicken prepared with liquid smoke. The order of presentation of the health claims and the environmentally friendly claims were reversed to measure the impact of the order of presentation on consumers' willingness to pay. An Nth type auction showed that health claims elicited a greater premium; the highest average premium was approximately $7 including the baseline price following the health claims for the liquid smoked chicken. The order of presentation of the information did not affect the results.

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Chapter 2
Seth Ellsworth, Philip Glen Crandall, Han-Seok Seo and Corliss A. O'Bryan. 2022. Consumers' willingness to pay for safer, more environmentally friendly smoke flavored chicken breasts. J. Sensory Studies:e12812. DOI: 10.1111/joss.12812

Thesis Introduction

The two papers combined in this thesis have a symbiotic relationship. The first paper, *Perspective on the control of invasive mesquite trees and possible alternative uses*, explores a looming environmental catastrophe caused by invasive mesquite trees across the world and potential uses including food application. The second paper, *Consumers' willingness to pay for safer, more environmentally friendly smoke flavored chicken breasts*, further expands on a food ingredient by-product of mesquite trees, liquid smoke. Liquid smoke is created by the condensation of smoke generated from mesquite biomass, which is an environmentally sustainable product. Moreover, the paper explores variables that influences consumers' willingness to pay for a liquid smoke poultry product. Finally, through an econometric statistical analysis, informational treatment effects: health benefit claims compared to environmental benefits claims are examined. By unlocking additional demand for liquid smoke products food manufacturers will not only be able to grow their product portfolio, but also increased demand for mesquite biomass used to make liquid smoke. The increased demand for mesquite biomass will in turn help provide a more stable commodity market for mesquite biomass, thus giving land managers more incentive to harvest mesquite trees— helping alleviate some of the problems resulting from invasive mesquite trees.

Chapter 1: Perspective on the control of invasive mesquite trees and possible alternative uses

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doi: 10.3832/ifor2456-011

iforest : Biogeosciences and Forestry

Abstract

Mesquite trees continue to invade forests and range lands in many countries across the world. The cost to remove these trees is staggering. In Texas, landowners spent $25 million over a 10-year period to clear 300,000 ha of mesquite trees, a fraction of the 22 million ha of Texas land affected by this invasion. Estimates are that the mesquite continues to negatively impact one to two percent of additional land in selected counties each year in Texas. However, the problem is not unique to Texas, but rather to the 44 species of mesquite trees, belonging to the genus *Prosopis* found in the pea family, the *Fabaceae*, introduced across the southern United States, South Asia, Africa, the Middle East, South America, and the Caribbean. In response, researchers are searching for economically viable uses for harvested trees and seeds to provide an alternative to the high cost of removal. If viable uses for harvested mesquite trees and seeds are found, then sustained pressure will limit and ultimately reduce the negative impact from these invasive trees. One key factor to controlling this invasive species is to find economically and environmentally sustainable uses to help pay the costs of removal or perhaps make removal less necessary. Traditional uses of mesquite are as a building material, as a source of food for both animals and humans and as wood for charcoal. Emerging uses of mesquite are new applications as a biofuel and as a bio-filter medium for water. Moreover, forestry land management of mesquite has adapted to include the tree as a component of hunting lands. New control methodologies and technologies are based on an increased understanding of mesquite growth patterns, using recommended practices that reduce control and eradication costs while improving the efficiency of land management. Previous land management practices have proven that excessive application of herbicides, physical removal of mesquite trees, or human-induced brush fires, if not carefully planned, only worsen mesquite infestations. The growing problem of mesquite land management

provides an opportunity for continued research into novel ways to utilize mesquite biomass, of both wood and seed pods.

Introduction

The 44 species of *Prosopis* (*Fabaceae*), commonly known as mesquite in the English language, khejri in Hindu, or algarroba in Spanish, are spread across large regions of the southern United States, South Asia, Africa, the Middle East, South America, the Caribbean (Burkart 1976, Rogers 2000). The origin of the *Prosopis* genus is traced to Argentina, where 34 of the 44 species are native to Argentina's northern region (Rogers 2000). It stands to reason that much of the research studying the biology of the *Prosopis* species are centered in Argentina at the Universidad Católica de Santiago del Estero (Ewens et al. 2012).

Texas, the second largest state in the United States of America (USA), has a land mass of nearly 70 million ha, 22 million ha of which have been reduced in value due to mesquite invasion. Mesquite's rapid expansion started when early cattle ranchers in Texas initially used mesquite seed pods as feed to supplement cattle diets during long cattle drives to Northern markets. While passing through an animal digestive tract, the mesquite seeds are scarified and then excreted in manure, which is a perfect growing medium. These processes contributed to mesquite's rapid expansion across much of Texas' rangeland (DeLoach, 1984).

Over the 10-year period from Fiscal Year 2000 to Fiscal Year 2010 the Texas State Soil and Water Conservation Board (TSSWCB) spent almost 50 million US $ treating approximately 300,000 ha with herbicides and the mechanical removal of this invasive species. The goal of the TSSWCB efforts were to enhance water availability through selective brush control (TSSWCB 2010). Mesquite trees have continued to invade additional land, increasing their coverage by about two percent annually in certain Texas counties, based on long term studies conducted since 1976, which observed the changes in honey mesquite (*Prosopis glandulosa*) canopy cover during a 20-year period (Ansley et al. 2001). Thus, mesquite continues to increase in land coverage in spite of huge expenditures on control measures. The immense density of the mesquite species invasion in the USA remains the highest in Texas (Fig.1). In addition to diminishing the value of Texas grazing lands, mesquite trees' expansion in southeastern New Mexico negatively impacted the breeding of lesser prairie-chicken (*Tympanuchus pallidicinctus*), a species of conservation concern (Boggie et al. 2017).

Mesquite trees are legumes and like many legumes have the ability to enrich the soil around their roots by fixing atmospheric nitrogen symbiotically with particular soil bacteria. This ability to enrich soil initially made them attractive to combat desertification, especially in arid African countries (Geesing et al. 2000, Shackleton et al. 2014). Members of the genus *Prosopis* are, in some aspects, the ideal candidate to combat desertification across wide expanses of the world because mesquite trees can grow in highly alkaline soils, tolerating a pH up to 9.5 to 10.0 and a soluble salt content between 0.54% and 1.0% (Rogers 2000). However, in many parts of the world their uncontrolled spread has significantly decreased the value of the rangeland they were meant to improve and enrich. Unfortunately, mesquite trees can quickly become a biological nightmare as happened in Sudan. Sudan once heralded the mesquite as the "miracle tree" that could help stave off the threat of desertification and increase the biodiversity in Sudan's deserts (Babiker 2006). However, mesquite now completely dominates portions of Sudan's once tillable farm land and has been reclassified as a noxious weed as part of their government-sponsored mesquite eradication program (Rogers 2000, Shackleton et al. 2014).

Prosopis juliflora trees have an extensive root system which have been found to penetrate as deep as 53 m (Jackson et al. 1996), and the *P. glandulosa*'s root depth has been recorded down to 50 m (Canadell et al. 1996). These deep root systems are combined with a surface root system that may cover up to 15 m in circumference, together making them a fierce competitor for soil moisture. Mesquite trees can become quite large with the honey mesquite known to grow to 7.6 m in height with its main support trunk as large as 0.6 m in diameter. Normally, a mesquite tree has a single main trunk with minimal ancillary branching; however, damage to the upper portion of the tree from either animal foraging or human eradication efforts, causes multiple re-sprouting of the stems which can exacerbate the problems of mesquite invasion. During a drought, vegetative growth stops, but will resume quickly after a period of rainfall. Flowering occurs as leaves develop and will later form the seed pods of the mesquite tree (Ansley et al. 1997).

As legumes, mesquite trees have a symbiotic relationship with bacteria of the genus *Rhizobium* in their root nodules, which is where atmospheric nitrogen fixation occurs in the soil. Increased understanding of biological nitrogen fixation has occurred by measuring nitrogen-fixation in *Prosopis glandulosa.* Soper et al. (2005) took samples from the entire nitrogen uptake pathway including soil solution, xylem sap, and foliage; a large variation of about 70% was found in nitrogen fixation values from each of these sampling locations. The quantity of nitrogen fixation is inversely related to the diameter of the mesquite tree (López et al. 1997). Thus, a younger mesquite tree will fix more nitrogen than a larger, more mature tree. This characteristic probably enables newly established mesquite trees to colonize in even the lowest fertility soils. Mature trees appear to obtain most of their nitrogen needs from the soil (Geesing et al. 2000). This fixation of nitrogen may be related to the fact that certain species of mesquite can grow in saline soils (soils with high levels of salt) with salt levels 10 times greater than the maximum salt levels tolerated by common commercial legumes, such as soybeans (Velarde et al. 2003).

Mesquite and some species of the genus *Acacia*, another nitrogen-fixing tree, have been estimated to be able to fix 30-40 kg N ha^{-1} $year^{-1}$ (Felker et al. 2013). Leaf and branch litter that fall from the mesquite trees was also shown to increase the resorption of nitrogen and phosphorus, further contributing to soil enrichment (Wilson and Thompson 2005). The increase in organic soil carbon from the decomposition of leaf and branch litter can contribute to the soil's water-holding and nutrient-binding capability, especially in sandy soils.

This review paper was researched by using search terms such as "mesquite,"-, "algarroba," "*Prosopis*," and "*Prosopis glandulosa*" in the Web of Science and Direct Science databases to generate the articles reviewed. We decided to focus on the particular mesquite species found in Texas, *P. glandulosa*, which has thus far eluded effective and efficient brush management over several decades. Personal interviews were conducted with mesquite management experts to understand in depth the issues facing brush management of the *Prosopis* species. While taking a cross-sectional review of potential solutions for *Prosopis* brush management around the world, this paper emphasizes *P. glandulosa* bush management in southwest North America as a focal point.

Control of mesquite as an invasive species

Careful and consistent land management is required to remove established mesquite trees and to prevent their aggressive reinvasion. Land managers have studied mechanical, chemical, fire, and biological control agents to control mesquite's unwanted growth which currently covers nearly one-third of Texas' pasture lands. In Texas, a mature mesquite tree can translocate as much as 167 L of water per day. TSSWCB estimated that removing 7 ha (17 acres) of established mesquite trees is equivalent of saving more than 1.2 million L of water per year (TSSWCB 2010).

A possible control mechanism for mesquite growth is to restrict groundwater availability in controlled areas. Empirical hydrological and vegetational data have been used to create a model for *P. velutina* to explore the capacity for translocation of ground water and the potential for damaging the development of riparian ecosystems. The model predicted that a stand of *P. velutina* with height greater than 12 m translocates groundwater from depths of approximately 6 m or less (Stromberg & Wilkins 1993).

In addition, access to ground water enabled the proliferation of the *P. pallida* on the highlands of Hawaii (Dudley et al. 2014). *P. pallida* in this region received more rainfall and developed differently from the lowland *P. pallida*, which received less rainfall and had greater access to groundwater. Moreover, the lowland *P. pallida* showed increased uptake rates of carbon (C), nitrogen (N), and phosphorus (P), which contributed to the access to groundwater. Indeed, higher N mass concentration in the soil as well as denser canopies, larger basal trunk area and larger leaf area were found in sites where *P. pallida* had access to groundwater. The use of various water sources was measured and confirmed by oxygen-stable isotope ratios. If access to groundwater is reduced by either humankind or natural methods linkage between groundwater and self-generated soil nutrients will be minimized (Dudley et al. 2014).

Seed pods of the mesquite tree were used extensively by early cattle ranchers to feed their livestock which contributed to the change in grassland ecology, especially in the Southern USA, Argentina, Australia and Africa (Archer et al. 1995). As cattle grazed down the grass, removing the principal vegetative competitor to the mesquite trees, the mesquite seedlings sprouting from piles of manure were able to rapidly encroach on the former grass lands. Once established, the extensive surface root systems of the mesquite trees acted as competitive growth inhibitors, preventing the grassland's regrowth after being over-grazed. Locations with high stock-loadings, even in different countries, have the highest density of mesquite because of the cycle of (1) cattle overgrazing, clearing the grasslands (2) the hungry cattle eat the mesquite pods, the cattle's digestive system scarifies the seeds which are then excreted in a manure rich environment—perfect for sprouting, and (3) these newly sprouted mesquite seedlings further inhibit the regrowth of grass while encouraging further growth of the mesquite seedling. The density of mesquite trees can be huge, up to 10,000 small (1 to 2 cm diameter) stems ha^{-1} in a new land that has been invaded for less than 10 to15 years (Patch and Felker 1997). Poor land management practices with years of sporadic mesquite treatments (herbicides, mechanical removal and control fires) only damage the above soil portion of the mesquite trees. Once damaged, the original few-stemmed trees regrow and resprout as multi-stemmed thickets, thus worsening the mesquites' negative impacts (Ansley et al. 1997).

Current control measures

Mechanical

Mechanical removal of mesquite trees has an immediate positive impact on mesquite tree control. Land managers use a specially designed deep-grubbing blade on a bulldozer or a track-hoe to remove the tree and root crown 20 to 25 cm below the soil, which is particularly effective. Afterwards, the rough ground needs are addressed, the pasture is re-seeded and spot application of herbicide on the regrowth and new seedlings is applied (Lyon, personal communication). Ill-timed or half-hearted mechanical removal of the trees just the above ground portion routinely leads to increased sprouting and increased density of the tree. Moreover, cuts must be made below the crown to ensure no resprouting. Newly sprouted seedlings can be killed if they are mowed off below the cotyledons, located approximately 2.54 and 3.81 cm above the ground. Optimal timing of mowing is between early spring and late fall when seeds typically sprout (Ansley et al. 2006).

Another method of reduction tested include competitive inhibition from grass roots as means to control mesquite growth (Johnson et al. 2000, Polley et al. 2003). Light levels of either low light level (6.0 ± 0.4% µmol (photon) $m^{-2} s^{-1}$ at the soil level and 8.3± 1.9% µmol (photon) $m^{-2} s^{-1}$ above the canopy) or high light level (18.9 ± 0.8% µmol (photon) $m^{-2} s^{-1}$ at the soil level and 15.0± 1.1% µmol (photon) $m^{-2} s^{-1}$ above the canopy), grass root exclusion to 0.15 m depth with 0.15 m diameter, and a control were tested. Perennial grass, a C_4, *Bothriochloa ischaemum* (L.) Keng, var. *songarica* (Rupr.), was used to impede the propagation of mesquite trees based on the hypothesis that the test grasses would more effectively compete for soil moisture. For the control, the soil moisture was reduced by about 3% from the original range of soil moistures of 28.4% to 27.4% down to 25.3% to 23.9% without grass. This reduction in soil moisture was accomplished by the use of canopies over the soil plots. This depression in soil moisture did not reduce the sprouting of mesquite seedlings nor did it inhibit the establishment of mesquite growth, but it did retard the growth of developing mesquite trees.

The CO_2 effects on soil moisture were explored by enclosing a grassland plot 20 m from the other testing sites present in the study. The enclosed plot was exposed to a constant and uniform gradient of 550 µmol/mol CO_2 concentration in two parallel, tunnel-shaped chambers, running from a north to south axis based on a previous field study (Johnson et al. 2000). The competitive grasses only reduced the number of seedlings that emerged, but the grass roots were not sufficiently competitive in restricting soil moisture to prevent the growth of mesquite. Finally, increased CO_2 atmospheric gas would only lead to further propagation of mesquite trees (Johnson et al. 2000). Moreover, the increased soil-water level allowed for further propagation of mesquite trees.

Burning

Controlled burning has been identified as probably the most cost-effective method of mesquite removal (Teague et al. 2001). Mature *Prosopis glandulosa* are fire-resistant, but the seedlings are more susceptible to damage by fire; therefore, properly timed fires can lead to a complete eradication of the mesquite seedlings in an area. A recent study demonstrated that timing and intensity of fires were important to control *P. glandulosa* (Ansley et al. 2015). Two plots of land were created with acid-scarified mesquite seeds planted in either mid-grass or tall-grass plots. The fields were then burned in either winter, when the seedlings were 10 or 22 months old, or late summer when they were about 17 months old. About 85% of the 17-month-old seedlings were destroyed in the summer burning compared to only 35% of the 10-month-old seedlings' being destroyed in the winter fires. Summer fires on land with low-grass cover were adequate to destroy mesquite seedlings. Therefore, the evidence suggested ranchers do not need to continue the current practice of deferred grazing to increase the grass biomass with the intent of building adequate burning foliage for winter fires.

Herbicides

Topical and/or root applications of herbicides are not able to achieve a 100% kill rate of mesquite trees, and, furthermore, moderate herbicide injury can lead to increased sprouting of the trees (Ansley et al. 2006). Herbicides have been heavily used to combat mesquite propagation; however, herbicides have proven ineffective as the complete solution to the mesquite problem (Bovey & Whisenant 1991). Furthermore, lands treated in the 1970's and 1980's by two treatments: (1) top-kill herbicides, and (2) root-kill herbicides, and a control were analyzed for cost-efficiency in treating mesquite trees (Ansley et al. 2004). The cost of using Triclopyr (3,4,6-trichloro-2-pyridinyloxyacetic acid, butoxyethyl ester), a top-kill herbicide alone, at an application rate of 0.56 kg ha^{-1} was reported to cost be 37 US \$ ha^{-1}, while the cost of using a mixture of 0.28 kg ha^{-1} Clopyralid, a root-kill herbicide, (3,6-dichloro-2-pyridinecarboxylic acid, monoethanolamine salt) plus 0.28 kg ha^{-1} Triclopyr was approximately \$62 ha^{-1}. Effective root-killing treatments cost between 60 and 70 US \$ ha^{-1} and must be continued for as long as 20 years, and top-killing treatments at 30 US \$ to 40 US \$ ha^{-1} need to be continued for more than 10 years to achieve cost-effective results (Teague et al. 2001). Only the root-killing herbicide regime gave an economic return, while top-killing herbicide treatment did not, analyzed on annual grass yields between 1998 and 2000. In addition, variation in increased grass yield from year to year made it difficult to determine which type of grass is better suited to compete or co-occupy land with mesquite. However, Buffalo grass (*Buchloe dactyloides*) was concluded to have the highest growth rate and to be the best competitor to mesquite regrowth (Ansley et al. 2004).

Alternative chemical treatments that allow treated mesquite lands to be used for multi-uses such as livestock production and wildlife habitat have been investigated (Ansley et al. 2006). Three different treatments by aerial spray: (1) untreated, (2) Clopyralid alone at 0.28 kg ha^{-1} and (3) 1:1 mixture of Clopyralid + Triclopyr at 0.28 +0.28 kg ha^{-1} were applied on two separate plots that were 80 km apart. Each treatment was replicated four times. The highest root kill rate using Clopyralid and Triclopyr was 56.7% with a standard error of 5.8%, further substantiating that that herbicides alone are not a final solution. On the other hand, the data demonstrated that herbicides can be used to manage the brush in a savannah ecosystem which appeals to modern management goals in maintaining diversity and creating multiple use options of rangelands (Cairns & Lackey 1992, Fulbright 1996). The authors attribute the variability to the difference in soil composition and vegetation surrounding the mesquite trees on the two separate plots.

Biological Control

The use of biological control agents, such as plant eating insects, was suggested as a low-cost method to control the growth of mesquite (DeLoach 1984). Over 300 insect species have been identified in Argentina and Paraguay that feed on the 30 different *Prosopis* species. The 10 most effective insect species identified were seed-feeding bruchid beetles belonging to the genera *Rhipibruchus*, *Scutobruchus*, *Pectinibruchus*, and *Acanthoscedlides*. These insects feed on the developing seeds of the mesquite, thus limiting and controlling the spread of mesquite trees. Other insects including gelechiid leaf-tier from the *Evippe* and the *Recurvaria-Aristotelia* group were identified as insects that fed on the mesquite's foliage. However, non-native insects as biological control agents for mesquite have never been cleared for introduction in the USA.

Biological controls were used in other countries for various *Prosopis* spp. with mixed results (Van Klinken et al. 2003, Hamilton et al. 2004, Shackleton et al. 2014). For example, Van Klinken et al. (2003) evaluated the potential effects of *Evippe* and *Prosopidopsylla flava*, biological control agents from Argentina, in a study performed in Australia. *Evippe* flourish in the Australian climate, but the researchers were unable to predict how the insects' defoliation efforts affected the developmental rates, survival or reduction of mesquite trees. Moreover, despite the *Prosopidopsylla flava*'s coming from the same region in Argentina as the *Evippe*, *Prosopidopsylla flava* failed to achieve the population density to make a substantial impact on the mesquite trees (Van Klinken et al. 2003)

Estimation Tools

Innovation with brush management allows for more precise control of growth of *Prosopis* spp. Researchers combined the National Agricultural Imagery Program (NAIP) and a moderate-resolution (30m) Landsat-5 Thematic Mapper (TM) imagery to create free-of-charge maps that can be used by land managers to increase cost-effective methods of monitoring and controlling mesquite growth (Collins et al. 2015). The maps help the land owner decide where efforts need to be allocated to best manage the land and focus resources on key-targeted areas. In addition, The Texas Extension Service also has a tool to help estimate the economic cost of mesquite tree removal through various methods (Texas A&M Agrilife Extension 2016). This tool gives a rough estimate of the cost associated with mechanical or chemical removal of mesquite depending on the density of the mesquite trees and the location of the area to be cleared. For example, when land managers rent equipment for mechanical removal or contract chemical spraying companies, they can use the tool to: (1) estimate how many mesquite trees need to be removed to make their work economically impactful and (2) where they should concentrate their efforts based on digital imaging of the coverage of mesquite trees on their property.

Alternative applications of mesquite

Food

There is a developing trend to find economically viable uses for harvested mesquite trees and seeds to put sustained pressure on the ecosystem that will limit and ultimately reduce the negative impact from these invasive trees (Shackleton et al. 2014). A review by Felker *et al*. (2013) investigated the genus *Prosopis*, describing potential food applications which are similar to the food applications of the carob tree (*Ceratonia siliqua*)—cultivated in Spain. Spain is the largest exporter of carob (the fruit pod from *Ceratonia siliqua*) at 26,185 tons year^{-1} (FAOSTAT, 2016). Carob can be formed into a powder that is used as a chocolate substitute, a caffeine-free coffee substitute, and a gum similar to gum arabic (Barak & Mudgil 2014).

Most of the *Prosopis* pods are from wild sources that are picked by hand with little automation. The pods are screened and then ground and sieved until the correct particle size is obtained for various products (Felker, personal communications). Studies on human food products sourced from the *P. glandulosa* are limited because of the high labor cost associated with harvesting the pods and the lack of established markets. See examples of different *Prosopis* pods in Fig. 2.

While pods are a direct food from mesquite trees, an indirect food created by the mesquite trees is honey. Mesquite trees are a rich and popular source of nectar for honey bee production (DeLoach 1984). Mesquite honey, currently imported from Mexico into the USA, costs approximately $7.93 kg^{-1} (AMS 2016). Mesquite honey can also be found in the USA, but USA mesquite honey is not tracked by the USDA's national honey report. In 2015, the economic value of honey produced in the USA was an estimated 327 million US $ (NASS 2016). The USA market demand for honey may increase the economic value of mature mesquite trees used by bees to produce honey in the USA, thus improving rancher land management returns. Bee foraging was measured to understand flowering and pod production of the *P. glandulosa var. glandulosa* in relation to honeybee pollination. The increased number of pods from the tree had an association with increased number of visitation by bees regardless of the nectar production (Lee & Felker 1992).

Most mesquite trees in Peru are used as a source of fuel to cook meats similarly to the use of mesquite in the USA for barbeques. However, unlike the USA, Peru does not view its species of mesquite as a noxious weed and is not seeking to eradicate it. The Peruvian *Prosopis pallida* has been investigated by the experiment station of the University of Piura since 1984, seeking to develop value-added products from the tree's fruit pods in lieu of using the tree as fire wood. Products developed from the mesquite pods include gluten-free flour, caffeine-free coffee bean substitutes, and a syrup called algarrobina (Grados & Cruz 1996). Algarrobina is similar in appearance to molasses and is found to have a high sugar content up to 50% of algarrobina and a fiber content up to 32% of algarrobina (Bravo et al. 1998). Peruvian products, including the flour and algarrobina, have received USDA certified organic status in the USA. However, the algarroba products (which includes those from both *Ceratonia siliqua* and *Prosopis* species) are still an emerging industry and are yet to gain a large foothold in the international market (FAOSTAT 2016).

A gluten-free flour made from the seeds of another heavily studied species, *Prosopis alba,* has a unique flavor and aroma (Takeoka et al. 2008). The mesquite flour was determined to contain 2, 5-dimethyl-3 ethylpyrazine (4.8% of the total volatiles), which has a pleasant cocoa, chocolate, burnt almond and filbert-hazelnut aroma with a low odor of threshold of 0.4 ppb. In addition, (y)-octalactone (0.4%) and (y)-nonalactone (1.6%) lend a coconut aroma (Felker et al. 2013). The chemical and nutritional properties of different fractions of *Prosopis alba* pods and seeds has also been studied (Sciammaro et al. 2016). The whole seed contained 34% protein, while the whole pod flour contained 5.8% protein, and the pulp (pericarp) flour contained 3.5% protein. In addition, the whole pod flour was found to have 44% sucrose compared to 41% sucrose in pulp flour. Another highlight of the analysis was iron content was approximately 57 ppm in pods and approximately 54 ppm in pulp flour, which could supplement a person's diet to meet the recommended daily intake of iron. Soluble dietary fiber was reported on a dry weight base as approximately 25% for pod flour total dietary fiber (84% of it being insoluble dietary fiber), while pulp flour was reported as about 23% total dietary fiber (95% of it being insoluble fiber). Because the flour is gluten-free, the flour could be used in bakery formulations for the large and growing gluten-free bakery goods market (Sciammaro et al. 2016).

In addition, the gum made from the *Prosopis* spp. is comparable in functionality to other gums such as gum arabic (López-Franco & Goycoolea 2006). Mesquite pod gum can be used as an emulsifying and stabilizing ingredient. The greatest difference between the *Prosopis alba* (mesquite) gum and the gum arabic (*Acacia senegal*) is the mesquite's higher protein content (Vasile et al. 2016). The researchers documented that the mesquite gum was able to better reduce interfacial tension compared to gum arabic measured by interfacial tension oil-in-water emulsion interfaces. In addition, the volume droplet size distribution for emulsions containing 2% of mesquite gum had monomodal distribution of 0.7 to 60 μm while gum arabic has a much broader range of droplets, 0.7 to 200 μm, suggesting mesquite gum is a more consistent emulsifier than gum arabic. The mesquite gum's improved interfacial and emulsifying properties are attributed to the mesquite gum's higher protein content (Dickinson 2003, Randall et al. 1988, Román-Guerrero et al. 2009).

Lumber

A publication of the Texas Forest Service (Rogers 1986) compared the properties of *Prosopis glandulosa var. glandulosa* to other woods. The mesquite lumber was superior to almost all of the other woods in every category except for bending strength (Tab.1). The mesquite ranks the lowest in volumetric shrinkage, about one-fourth that of other woods. The low volumetric shrinkage in mesquite woods is desirable as long as the shrinkage remain uniform within the wood. In addition, its radial and tangential shrinkage are almost equal, which reduces stress on the wood during high moisture building, i.e. seasonal weather changes. No other wood compared during the test exhibited these same properties. However, one disadvantage explained by the author is mesquite wood can have a high variation in density, bending strength, volumetric shrinkage and radial shrinkage (Tab. 1 and 2). The properties can have more than 300% variation in the volumetric trait of the wood, but overall, the volume shrinkage is still lower than any other wood (Rogers 1986). To maximize the trees used for lumber from *P. glandulosa var. glandulosa*, Felker *et al*. (1990) calculated 100 stems ha^{-1} would generate the optimal base diameter of the mesquite tree in 35 cm, to yield the most lumber. The calculated optimal spacing of 10 by 10 m was later confirmed in a follow up study (Patch and Felker 1997). In addition, the optimal basal diameter growth of 1.2 cm^{-1} yr^{-1} was obtained when disking and pruning treatments were applied to the mesquite tree grove over 9 years.

Hardwood sawn timber has historically garnered higher prices than pulpwood with an average of 20.40 US \$ ton^{-1} (Adams et al. 2015). In the Timber Mart-South 2016 second quarter report, mesquite pulpwood averaged around 10 US \$ ton^{-1} and sawn timber averaged 25 US \$ ton^{-1} (TimberMart-South 2016). Since mesquite is not harvested on a large commercial scale within the USA, reports will show mesquite wood mixed with other hardwoods. For example, the hardwood pricing publication Hardwood Review Global did not report a specific cost for mesquite, while reporting many others like cottonwood, cherry, hard maple, hickory, red oak, white oak, and walnut (Hardwood 2016).

Moreover, through efforts to understand the mesquite lumber market, communication from the College Station Cooperative Extension office reported that a St. Angelo, TX, company is harvesting mesquite - grinding, pelletizing and shipping it overseas for pellet stoves. In addition, another land owner cut and sold the mesquite wood he grubbed from his land as firewood. His sales of firewood paid for most of his removal cost. He also stated that land owners must do yearly follow-up to maintain control of the mesquite regrowth (Lyon, personal communications).

Biofuel

Crop residues, forest residues, grasses, and woody species may be used as lignocellulosic biomass to produce second generation bio-fuels. Reduction of greenhouse gas relative to petroleum gasoline was reported to be 19-48%, 40-62%, 90-103%, 77-97% and 101-155% from corn ethanol, sugarcane, corn stover, switch grass and *Miscanthus* spp. grass, respectively (Wang et al. 2012). Ansley *et al*. (2010) analyzed mesquite's potential use as a biofuel and found not only would harvesting mesquite be economically feasible and sustainable, it also would yield other ecosystem benefits, including increased grass and foliage production for livestock foraging. The approach to control mesquite through biofuel production could benefit both the rancher and the green energy producer.

Moreover, the economic and greenhouse gas impact of *Prosopis glandulosa* was assessed over the southern great plains (SGP) of the USA (Wang et al. 2014). Researchers wanted to look at new sources of biofuel that could replace grain-based biofuels. The assessment compared mesquite against other regional bioenergy feedstock in the SGP and demonstrated that mesquite was better than all other feed stocks in sequestering greenhouse gases, offsetting inefficiency, and increasing greenhouse gas use efficiency when land use change is considered. At a total cost of about \$121 ha^{-1}, the mesquite was found to produce energy levels of 43.34 GJ ha^{-1} (Tab. 3). Regrowth of the mesquite trees occurs in about half the time to grow a tree from seed (Ansley et al. 2010). This leads to obvious problems for land management as evidenced by the continuing reinvasion of range land by mesquite trees; however, the mesquite tree's ability to regenerate quickly makes it an ideal candidate for biofuel as biomass material.

The biomass needs of *Prosopis glandulosa* for gasification amounts and processes have been quantified (Chen et al. 2012). A small-scale biomass energy conversion plant was created to use brush material such as mesquite or redberry juniper (*Juniperus pinchotii)* as fuel in a small-scale (10kW) batch-type, fixed-bed gasifier. The effects of equivalence ratio, particle size, moisture content on the temperature profile, gas composition, and higher heating value (HHV) of both mesquite and redberry juniper wood were analyzed. When N_2 was removed, the HHV of the gas end product of the mesquite and redberry juniper wood was 26% and 27.5%, respectively, with the equivalence ratio being 2.7. In follow up study, they looked at the tar formation and yield from gasification of mesquite and juniper wood in an updraft gasifier. Mesquite wood energy yield was found to be up to 3.5MJ kg^{-1} when the moisture of the wood was at an ideal 6%. In a follow up study, the gas yield formation from the mesquite ranged from 0.51 to 0.31 per unit mesquite in the gasification process (Chen et al. 2015).

Similar biofuel research on mesquite has been conduction in Turkey. Syrian mesquite (*P. farcta*) was investigated in Turkey for bio-oil production via catalytic supercritical liquefaction (Aysu & Durak 2016). *P. farcta* was used in a catalytic reaction using $ZnCl_2$ and NaOH. Acetone was held at 295˚C, which achieved a liquid yield of 49.7%, indicating that most of the biomass was recovered as bio-oil, with HHV between 20 and 34 MJ kg^{-1}.

Biofilters

Mesquite wood chips have also been tested as an organic filter material (OFM). An OFM is an organic material that retains different pollutants that later biodegrades into to CO_2, H_2O, and N_2. An OFM can be used as a bio-filter over an organic bed system, serving as a decentralization technology alternative to conventional municipal wastewater treatment (Sosa-Hernandez et al. 2016). This research investigated mesquite wood chips as an organic filter material that met both Mexico's and USA's regulations for reuse in irrigation. The optimal hydraulic loading rate over 200 days of testing was 1.07 $m^3 m^{-2} d^{-1}$: This resulted in a removal efficiency of biochemical oxygen demand by 92%; and a reduction of the chemical oxygen demand by 78%. The total suspended solids were reduced by 95% and there was a four-log reduction of fecal coliforms. These reported variables contributed to a mesquite wood chip OFM's meeting the critical requirements of wastewater treatment for reuse in irrigation set by the USA and Mexican governments. Thus, the novel use of mesquite wood as a bio-filter was deemed viable.

Human Challenges to Control

Discussed throughout this paper are different options available for the uses of mesquite. However, the viewpoint of the very small landowner who may rely upon mesquite for his or her livelihood should not be overlooked. Farmers in South Africa will serve as example to illustrate this point. Shackleton *et al*. (2014) investigated different stakeholder viewpoints in South Africa: farmers, urban-informal, urban-affluent, and communal areas. All considered the costs of *Prosopis* to be greater than the benefits. However, even when they understood the invasive nature of *Prosopis*, approximately 63% of farmers continued to use the *Prosopis*' pods as fodder for their livestock. Two other common uses of *Prosopis* were fuelwood and shade. Thus, these applications may continue to make livestock owners more dependent on *Prosopis* products and lead to their resistance to control. In addition, governments and NGOs may promote utilization as a means of mesquite control even though utilization of mesquite alone has been proven insufficient to contain the problem of mesquite's rapid growth. Both of these efforts may lead to ongoing invasions. When the intent is unambiguously to restore invaded areas to productivity, then alternate uses can be a way of offsetting the control costs. Furthermore, the economic cost to run an efficient land management program is a barrier: the estimated control cost for appropriate mesquite management (>9.5 million US $ yr^{-1}) far surpasses the entire budget of the Public Work programs of South Africa (Wise 2012).

Conclusions

The applications for mesquite trees and their products are nearly limitless, but how to manage mesquite tree's invasion of lands still eludes researchers and government agencies alike. Mesquite tress were once heralded as the salvation of arid land as result of the *Prosopis* species' ability to fix nitrogen, enriching the soil; however, governments latter realized the water demand of mesquite tree outweighed its benefits. The uses of mesquites trees included food for human or animal consumption, lumber, biofuel, and an emerging application as an organic bio-filter. Land managers have tried to control mesquite growth through mechanical, burning, herbicides and biological control methods. However, humans mixed relationships with mesquite uses from different economical functions in society compound the problem to effectively control mesquite afflicted lands. As discussed in this article, many years of research have been spent on unlocking the uses of mesquite trees. However, the growing problem of mesquite land management still provides a rich opportunity for continual research into new ways to utilize mesquite lumber and seed pods in an environmental and economical sustainable manner.

Acknowledgements:

Dr. Peter Felker provided valuable insight from his past work when contacted for this paper. Funding from a USDA SBIR project is appreciated.

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PROPERTY	MESQUITE[1]	SOUTHERN[2] RED OAK	MOCKERNUT[3] HICKORY	PECAN[4]	LOBLOLLY[5] PINE	SUGAR[6] MAPLE	EASTERN COTTONWOOOD[7]
DENSITY (KG M^{-3})	721	589	719	660	509	630	449
BENDING STRENGTH MOE* (KPA)	9,515	10,273	15,306	11,928	12,342	12,617	8,963
VOLUMETRIC SHRINKAGE (%)	4.7	16.1	17.8	13.6	12.3	14.7	13.9
(RADIAL/TANGENTIAL SHRINKAGE)**	2.2/2.6	4.7/11.3	7.7/11.0	4.9/8.0	4.8/7.4	4.8/9.9	3.9/9.2
SIDE HARDNESS (KG)	1060	481	1089	826	313	658	195

Tab. 1. Selected physical and mechanical properties of mesquite (*Prosopis glandulosa* var. *glandulosa*) and various other fine woods (commonly used values) (Rogers, 1986). [1]*Prosopis glandulosa* var. *glandulosa.* [2]*Quercus falcate* Michx. [3]*Carya tomentosa* Nutt.[4]*Carya illinoinensis* [(Wangenh.) K. Kock).[5]*Pinus taeda* L. [6]*Acer saccharum* Marsh. [7]*Populus deltoides* Bartr. *MOE= modulus of elasticity **Unitless

PROPERTY	LOWEST	HIGHEST	"PUBLISHED AVERAGE"	AVERAGE PERCENT DEVIATION
DENSITY (KG M^{-3})	639	987	721	54.4
BENDING STRENGTH MOE* (KPA)	4220	9935	9515	136
VOLUMETRIC SHRINKAGE (%)	1.8	7.5	4.7	316.7
SIDE HARDNESS (KG)	549	1,365	1060	149

Tab. 2. The variation in the physical and mechanical properties of mesquite wood (*Prosopis glandulosa* var. *glandulosa*) as tested by the Texas Forest Products Laboratory over a 15-year period (Rogers 1986). *MOE= modulus of elasticity

ITEM	SWEET SORGHUM		SWITCHGRASS	MESQUITE
	Irrigated	Dryland	Maintenance	-
AI	1,745.47	748.83	519.68	121.41
BIOMASS (MG HA^{-1})	17.79	6.93	12	2.2
ENERGY CONTENT (GJ HA^{-1})	410	166	189.6	43.34
GREENHOUSE GAS EMISSION	1,256	439.4	354.09	108.52
GREENHOUSE GAS OFFSET	7,455	2,904	4,050	1,100
NET GREENHOUSE GAS OFFSET (WITHOUT LAND USE CHANGE EFFECT)	6,199	2,464.6	3,695.91	991.48
GREENHOUSE OFFSET OF ALTERNATIVE CROP	3,370	1,500	1,500	-
GHG OFFSET (WITH LAND USE CHANGE EFFECT)	4,085	1,404	2,550	1,100
NET GHG OFFSET (WITH LAND USE CHANGE EFFECT)	2,829	964.6	2,195.91	991.48
COST/BIOMASS ($ US/MG)	98.115	108.056	43.307	55.186
COST/ENERGY ($ US/GJ)	4.257	4.511	2.741	2.801
COST/NGO ($ US/CARBON EQUIVALENT, WITHOUT LAND USE CHANGE EFFECT)	0.282	0.304	0.141	0.122
COST/NGO ($ US/CARBON EQUIVALENT, WITH LAND USE EFFECT)	0.617	0.776	0.237	0.122
GREEN HOUSE GAS EFFICIENCY (WITHOUT LAND USE CHANGE EFFECT)	5.936	6.609	11.438	10.136
GREEN HOUSE GAS EFFICIENCY (WITH LAND USE CHANGE EFFECT)	3.252	3.195	7.202	10.136

Tab. 3. A comparison of the sweet sorghum, switchgrass, and mesquite production systems (Wang et al. 2014).

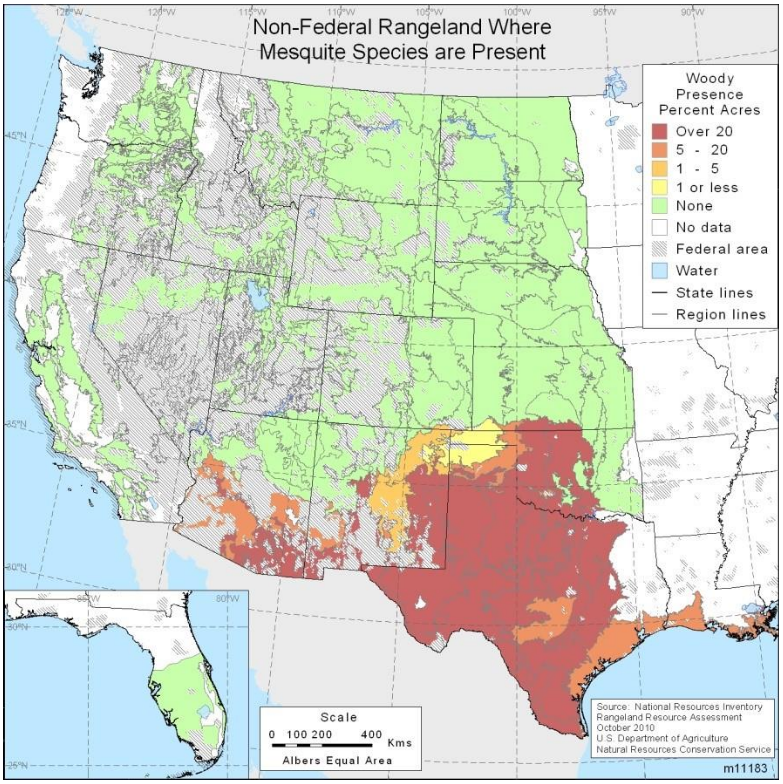

Fig. 1. Adapted map of non-federal rangeland where mesquite species are present (FSIS-USDA, 2016).

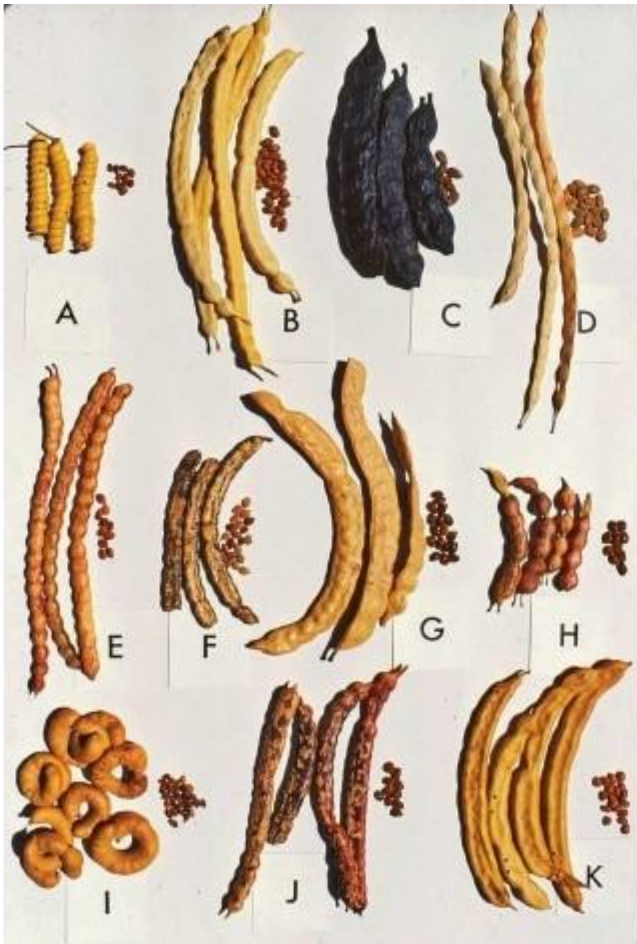

Fig. 2. Prosopis pods of various species and origins. Screwbean from California, *P. pubescens* (A); mesquite from California, *P. glandulosa* var. *torreyana* (B); itin from Argentina, *P. kuntzei* (C); mesquite from Baja, California, *P. articulata* (D); algarrobo from Catamarca, Argentina, *P. flexuosa* (E); algarrobo negro from Argentina, *P. nigra* (F); algarrobo blanco from Santiago del Estero, Argentina, *P. alba* (G); mesquite from New Mexico, *P. glandulosa* var. *glandulosa* (H); tamarugo from the Atacama Desert, Chile, *P. tamarugo* (I); Mesquite from south Texas, *P. glandulosa* var.*glandulosa* (J); and mesquite from Senegal, P. *juliflora* (K) (Felker et al. 2013).

Chapter 2: Consumers' willingness to pay for safer, more environmentally friendly smoke flavored chicken breasts

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DOI: 10.1111/joss.12812

IRB #1806126303

Abstract

Boneless, skinless chicken breasts comprise almost 30% of total poultry sales and poultry remains US consumers' protein of choice. This research sought to determine whether consumers of chicken would pay a premium for a smoked chicken breast that was healthier and produced with less of a negative impact on the environment. Two balanced consumer panel groups were presented with information on the two value prospects of smoked chicken prepared with liquid smoke. The order of presentation of the health claims and the environmentally friendly claims were reversed to measure the impact of the order of presentation on consumers' willingness to pay. An Nth type auction showed that health claims elicited a greater premium; the highest average premium was approximately $7 including the baseline price following the health claims for the liquid smoked chicken. The order of presentation of the information did not affect the results.

Practical applications: Consumers are willing to pay more for chicken that is deemed healthier and prepared with environmentally friendly ingredients.

Keywords: Smoked chicken; N^{th} type auction; liquid smoke; willingness to pay

1. Introduction

Consumers are increasingly concerned about a multitude of factors which influence their food purchases. Top concerns are related to (1) the environmental impact of the production of their food, (2) the benefit their food purchase will have on their or their family's health and (3) an understanding of how their food products are made (Lee & Yun, 2015). Consumers often must choose among competing attributes because each new food product typically only has some, not all, of their desired attributes. In a study that looked at the tradeoffs between taste and health benefits for functional foods researchers found that consumers were willing to partially sacrifice good taste for perceived health benefits (Papoutsi et al., 2019). Moreover, consumers have also been shown to be willing to pay more for food products that have positive environmental impact, especially products that can be produced with lower greenhouse gas emission (GHG) (Akaichi et al., 2017).

With both traditional smoking and manufacturing of liquid smoke, pyrolysis, heating wood to its smoke point in an oxygen restricted atmosphere, produces chemical byproducts called polycyclic aromatic hydrocarbons (PAH) (Lingbeck et al., 2014; Šimko, 2002). Several types of PAH can be formed with benzo[a]pyrene (B(a)P) serving as a proxy measurement for the total PAH present in smoked foods (Šimko, 2005). B(a)P at levels of 300 ppm have been shown to cause birth defects in pregnant mice and levels above 900 ppm produced liver and blood defects in test animals (EPA, 2017; Hardonniere, et. al., 2016). The European Food Safety Commission (2002), the USA Environmental Protection Agency and World Health Organization, have labeled PAHs as being carcinogenic in humans (WHO-FAO, 2009). Choosing to use liquid smoke over traditional smoking techniques can significantly reduce the levels of PAH because of the difference in water solubility (Lingbeck et al., 2014). In addition to the health benefits, liquid smoke production reduces the manufacturing carbon footprint by as much as 80% when compared to conventional wood smoking (Jenkins, 2009).

Studies involving willingness to pay (WTP) are an established way to evaluate how an individual values a food they are considering for purchase. WTP studies have been used to price new retail products and to estimate consumers' valuation of certain food product label claims (Janssen & Hamm, 2012) or for consumers to place a value on the environmental costs of producing a product (Kling et al., 2012). WTP is important to both food manufacturers in their R&D process but also to economists and marketing researchers (Steiner et al. 2016), making accurate measurements of consumers' WTP essential. l

Our preliminary research established that most consumers on these two panels were not familiar with the health or environmental benefits of liquid smoke. In addition, a survey of the common liquid smoke brands in retail markets in the USA (Colgin, Wright or Fiargo) demonstrated a complete lack any promotional labeling that highlighted either of the benefit claims evaluated in this experiment. The liquid smoke industry may be missing a significant opportunity as more and more consumers' desire increased information about the environmental impact and how their retail foods are made. This study examines how routine consumers of poultry willingness to pay (WTP) was influenced by two pieces of framing information in a non-hypothetical auction setting. Chicken meat, a common protein used for smoked foods, was used as the stimulus. The objectives of this research were to determine if the order of presenting the framing information on the benefits of using liquid smoke as opposed to conventional wood smoking of chicken affected consumer choice, acceptance, and their WTP for two types of smoked chicken breasts.

2. Material and Methods

2.1 Participants

A total of 120 consumers were screened for their routine consumption of chicken or smoked chicken from a consumer profile database of the University of Arkansas Sensory Science Center (Fayetteville, AR, USA). Respondents were randomly divided by gender and assigned to the two treatment Groups A or B. Group A was 57% male and 43% female while Group B was 59% and 41% female. Group A's age year group ranged from 18-19 (35%), 40-39 (28%), 40-40 (11%), 50-65 (20%) and 66+ (6%). Group B's age year group ranged from 18-19 (33%), 40-39 (14%), 40-40 (24%), 50-65 (24%) and 66+ (5%). Prescreening questions helped ensured the two panels were evenly balanced. Panelists in Group A received the formatting health information first followed by the technology and environmental information. Group B received the same information but in the reverse order. The formatting script which was read by the moderator is given in Table 1. The protocol used in this study was approved by the Institutional Review Board of the University of Arkansas, IRB #: 1806126303. (Fayetteville, AR, USA). Prior to participation, an informed written consent was obtained from each participant.

2.2 Chicken Preparation Methods

A single lot of commercial chicken was purchased from a retail establishment (Sam's Club, Fayetteville, AR) and two subsamples prepared from this single lot. Two types of smoked chicken were prepared in a USDA approved pilot plant at the University of Arkansas: conventional wood smoked chicken and liquid smoked chicken. The method of preparation followed similar methodologies for the smoked chicken breast found in Jaffe et al. (2017) and Samant et al. (2016) with some modifications. An Alkar smokehouse (Model 100; Lodi, WI, USA) with hickory wood chips was used to produce the conventional wood smoked chicken. The same smokehouse was used to atomize the liquid smoke to create the liquid smoked chicken. The liquid smoke used was Zesti Smoke© (Hickory, Kerry American Region, Monterey, TN, USA). A thermocouple probe was inserted into sample chicken breasts throughout the smoking process with an external monitor used to measure the internal temperature of the breast meat without having to open the smokehouse unit. The temperature probes were inserted into the innermost part of the chicken breast to ensure that the innermost temperature reached 74 ˚C for food safety. The samples were then cooled and cut into 1.2 cm cubes, and frozen at approximately 0˚C. Before serving, the samples were thawed in a refrigerator at 4 ˚C. The samples were then reheated in a microwave to 76 ˚C (approximately 30 seconds of cooking time) to induce sensory cues and flavor interaction (Bajec et al. 2012; Ross and Weller 2008; Talavera et al. 2007). After cooking each sample was tested with a thermometer to ensure they were at the correct serving temperature, 60 to 65 ˚C. The samples were then placed into labeled plastic sample cups for participants to taste before the auction began.

2.3 Nth type auction

This study was conducted using two random N^{th} type auctions to incentivize panelists to express their true willingness to purchase (bid) for a liquid smoke treated chicken breast. Furthermore, panelists were endowed with traditional smoked chicken breast and cash to reduce panelist bias (Shibata, et al 2021). Previous research has shown that N^{th} type auctions minimize the number of minimal or zero bids and have been shown to keep bidders engaged in each round of bidding because of the possibility of a large number being drawn randomly at the end of each round of bidding which would give many of the bidders the opportunity to exchange their traditional smoked chicken breast for a liquid smoked breast. Bidders are inclined to bid their true valuation of the product because they do not know the winning price or how many winners there will be in each round (Shogren et al., 2001). An explanation of how the N^{th} auction operated was given orally to each panel group. Then each group participated in a practice N^{th} bid price auction after initially being endowed with a small chocolate candy bar then being allowed to bid to upgrade for a larger candy bar. For each group, the panelists' bids were collected and organized from highest to lowest. A random number, n, was then drawn from a box containing the numbers between 2 to *k* (with *k* representing the total number of bidders). One was subtracted from the randomly selected *n* number and became the N^{th} bid price. The selected bidders then paid the corresponding N^{th} bid price as the market price and exchanged their small bar for a larger chocolate candy bar. Both numbers were drawn in plain sight of the participants to reinforce the consumers' expectation that the numbers were drawn randomly. Thus, participants were incentivized to only bid their true WTP instead of facing peer pressure to increase their WTP as in the traditional auction format where the only successful bidder must beat everyone else's highest bid.

2.4 WTP Experiment

The retail price comparison for 0.12 kg (0.25 lb) of commercially prepared smoked chicken breast was obtained by contacting seven local restaurants that prepared smoked chicken for their menu using the traditional wood burning methods. The average local restaurant price was about $3.50 for a 0.25 lb of commercially prepared smoked chicken breast. All participants were initially endowed (given) this sample of 0.25 lb of wood smoked chicken to reduce overbidding by the participants and to establish a baseline. Panelists were told that the cash ($20 dollar) participation fee they were given was their money as payment for their participation in this study. The panelists were given the money in a sealed envelope and instructed not to open it until the conclusion of the auction to help prevent any endowment effect of the cash and prevent perception that the money could be viewed as “house money” (Gracia et al., 2009). Treatment A in Round 1 had a control biding round where no information was presented about either smoked product to establish a base price. Then participants in Treatment A were read the formatting information in Round 2 of bidding about the health impact of smoked foods. In Round 3, participants were told about the technology (environmental benefit) of liquid smoke. Likewise, Treatment B panelists were given the identical information, only the order of the framing information was reversed. The selected bidders (everyone who placed a bid higher than the Nth binding bid number) then paid the corresponding N^{th} bid price as the market price and exchanged their endowed conventional smoked chicken for the liquid smoked chicken breast.

2.5 Statistical Analysis

The data was analyzed using an ordinary least square (OLS) and in the Tobit model (Henningsen, 2011a, b). OLS seeks to model the coefficient of linear between one or multiple dependent values X and a single dependent variable Y. This minimizes the sum of squares of distances between the observed and predicted response values, where the predicted response is calculated by adding the intercept to the linear combination of the explanatory variables and the parameter estimations (Hutchinson, 2011; Menard, 2000). However, the OLS is generally not preferred in WTP studies, because the estimates become inconsistent when the dependent variable data occurs with a negative or a zero value. Therefore, Tobit models are often preferred for estimating the willingness to pay.

The Tobit model was created by Tobin (1958) for analyzing economic data comparing household incomes and expenses for several goods, including luxury goods. Low-income households naturally would spend no money at all on luxury goods, causing the regression line for low-income households to be negative. In this model, also known as the censored regression model, there may be no dependent variable value for some observations, but the inconsistent results of the OLS model become consistent using the Tobit model (Noor et al., 2010). Tobit models are like the OLS model; however, a Tobit model allows the data to be truncated above (right-censored) or below (left-censored) a particular threshold preventing statistical noises. If a high number of zero bids were submitted, a Random Effect Tobit and Tobit Left Censored models were also run. The starting values for the Tobit model were obtained from the Wallace-Hussian estimator (Wallace & Hussain, 1969). The statistical analysis was conducted in R using the cenRegs Package (Henningsen, 2011a, b) and JMP Pro 16 software (SAS Institute Inc., Cary, NC, USA).

3. Results & Discussion

Treatment A, where the health information was presented first, had the highest average bid price, but the standard deviations between A and B bids were so large that there were no significant differences between the order of presentation of the formatting information compared to the reversed order in Treatment B. Both treatments showed an upward trend in the panelists' WTP after each round of providing additional formatting information after which participants were more willing to exchange their endowed conventional wood smoked chicken breast for the liquid smoked chicken breast at a premium price. The highest premium price paid was $7.00 above the baseline price or a total of $10.50, the participant's bid price + the stated $3.50 price for the conventional smoked chicken as presented by the moderator during the auction.

For both treatments the highest mean bid, for Treatment A was $1.28 and for Treatment B was $0.96, $t = 1.19$ and $p = 0.23$ thus, there was no significant difference in the highest mean bid between two groups was bid in Round 3 which was the last round of bidding when all the formatting information was available (Table 2). Moreover, the health information solicited the highest average bid price between the two treatments \$0.23 (Treatment A R2-R1 +Treatment B R3-R2) compared to only \$0.16 the average for the environmental information effect (Treatment A R3-R2 + Treatment B R2-R1). This was one of the key findings from this research, the comparative impact of the two types of formatting messages (Table 3). All information presented to the panelists had a significant effect on increasing the panelists' bid regardless of the order of presentation of the information. Likewise, the more formatting information a consumer heard about liquid smoke the higher the premium the consumer was willing pay to purchase a smoke flavored chicken breast prepared with liquid smoke (Table 3).

Reviewing the mean bid information from Figure 1, as the participants received additional formatting information about the liquid smoke the mean bid increased regardless of the order of information as tested between treatment A (a \$ 0.45 increase from the first round to the last round of the auction, which was significant $t = -4.31$ and $p < 0.001$) and treatment B (a \$0.26 increase from the first round when no information was present to the last round of auction $t = -2.33$ and $p = 0.02$) within the study. Jo and Lusk (2018) reported an interaction between the perception of healthy food health and how that perception positively impacted the price of the food. In essence the perception of the health benefit of a food can have positive increase in the taste and price of the food. While this study did not ask for participants to rate the taste of the product after each introduction of new information, a positive increase in the mean bid price was seen across participants. Further studies could explore taste perception after each new information is given. Furthermore, (Werle et al. 2013) highlighted the importance of how an underlying culture and associated product assumptions vary between cultures. This study was limited to participants that self-identified themselves as "White/Caucasian" and was limited to one site location located in Northwest Arkansas.

The impact from the N^{th} style auction and the sequential introduction of formatting information is shown in Figure 2. For both panels, A and B, there was a steady increase in panelist's positive participation by the increase in the number of active bidders for each round. Figure 2. The authors expected an increase in participation, based on previously published results on the N^{th} style auction. To this point, the Torbit model was run to minimize the impact of the zero, no bids. We considered only analizing the bids above zero for each Round, but this was idea was rejected because there was no way to know which panelist initially bid zero then participated in later rounds of bidding after listening to the formating information.

The frequency that a panelist reported that they consumed smoky foods and those with higher income were significant explanatory variables that could be used to help predict the bid premium for a panelist after performing a Tobit Left Censored analysis in R using the cenRegs Package (Henningsen, 2011b) and obtaining starting values through the Wallace-Hussian estimator panel model, following the treatment (the focusing information presented to the participates) (Figure 3). Likewise, the more formatting information a consumer heard about liquid smoke the higher the premium the consumer was willing pay to purchase a smoke flavored chicken breast prepared with liquid smoke (Table 3).

3.1 Panelists' demographics

A total of nine panelists' data were excluded from the study, six from treatment A and three from B, for a failure to provide complete information. This left a total of 54 participants for treatment A and a total of 58 participants for treatment B which is more than the minimum required (Gacula and Rutenbeck, 2006; Richardson, et al., 2021). The random assignment of panel members was found to be effective because there were no significant differences in the demographics between panels A and B based on: gender male 38.3 ± 14.5 for panel A and 40.2 ± 14.4 for panel B; the largest age group for both panels were in the 18 to 29 year age group, household income was nearly identical with the majority of both panels having reported income between $15,000 and $39,000/year, ethnicity was nearly identical with the majority of both panels comprised of white/Caucasian for panel A 80% and 78% for panel B. The amount of money routinely spent on food was identical between the two panels with the majority spending between $61 to $120 / week. Table 4. Time spent in meal preparation per week was not statistically different between the two groups of panelists. The data was compared using a Likert scale where 2 represented spending 20 to 40 minutes per day in meal preparation and 3 represented 40 to 60 minutes per day. Group A had a mean of 2.41 ± 1.17 and for group B the mean was 2.40 ± 1.20 (t =1.98, p =0.81) (Table 5).

There were also no significant differences between the two panels in their frequency of consuming meat. On a Likert scale where 5 represented eating this meat once per week and 1 represented never consuming this meat. The most frequently consumed meat for both panels was chicken with panel A mean 4.69 ± 0.80 and panel b 4.83 ± 0.50. Data not shown (t =-1.12, p =0.26). For both panels this was a good indication that these panelists ate chicken nearly once per week. This confirmed two things, first these consumers were indeed frequent consumers of chicken and the randomization of assigning panel members had been effective and there would be minimal demographic differences between the two panels (Table 6).

3.2 Emotional drivers for food choice.

It was important for the authors to understand the emotional aspect of panelists to their food choices prior to the auction. To this end, a series of written pre-test question were answered by each panelist (Table 7). Their ratings were given on a Likert scale, with 5 being extremely important and 1 being not important at all. For both groups of panelists, the strongest emotion coming into the test was the importance of “health benefits of foods to you”, which was tested by our initial formatting information. Panelists in treatment A ranked this benefit highest with a mean 3.83 ± 0.84 that was also the case for panelists in treatment B mean 3.88 ± 0.80 ($t = -0.30$ and $p = 0.77$). Fortunately, for the purposes of this study, the second highest ranked emotional aspect for both panels was to understand how one’s food was produced which reinforced the importance of providing the technological formatting information. Panelists ranked “understanding how your food is produced” for Panel A had a mean of 3.52 ± 0.77 and for panelists B the mean was 3.48 ± 1.00 ($t = 0.21$ and $p =0.83$). The environmental impact and “all natural” food label claims were not far behind with panelist A giving these a mean of 3.37 ± 1.00 and panelist B gave these a mean of 3.34 ± 0.97 ($t = 0.85$ and $p =0.40$). The final two questions probed the panelists’ understanding of the food ingredient liquid smoke. For both panels had some familiarity with this food ingredient, panel A’s mean was 2.57 ± 1.27 and for panel b 2.48 ± 1.37 ($t =0.37$ and $p =0.71$). Not only were values these the lowest means among the six questions asked but they had the largest variation as measured by their standard deviation. These scores demonstrated that both groups were well balanced in their attitudes towards the food attributes in question in this survey and familiarly, or lack thereof, with both how liquid smoke is produced and used in food production (Table 7).

3.3 Post survey questions

The panelists’ results to questions presented after the sensory analysis revealed that most of both panelists ate meat that had been smoked monthly but only had some familiarity with the liquid smoke food ingredient. There was no difference between the two panelists on the frequency of eating foods with a smoky flavor. Panelist A's mean was 1.19 ± 0.73 and panelist B mean was 1.05 ± 0.76 ($t = 0.95$ and $p = 0.34$) indicating they desired to eat smoky flavored foods about once per month (Table 8).

As evident by the participants' response to the survey questions, even among consumers who ate meat and smoky foods, panel members had little awareness related to either the health or environmental benefit of liquid smoke. Notwithstanding some participants who were familiar with liquid smoke, most did not know the favorable environmental impacts of how liquid smoke was produced. Further studies could evaluate a WTP surrounding a non-theoretical liquid smoke bottle label featuring additional information about how liquid smoke is processed, the health benefits of liquid smoke and the environmental benefits of using liquid smoke over conventional methods. Akaichi et al. (2017), further explained that relying on a food appearance or attributes without giving the consumer formatting context or relevant information diminishes the consumer's willingness to pay a premium for the product. Not only until consumer fully understand a food's benefits were consumer willing to pay a premium for the product.

Essentially, the combined statements describing the liquid smoke environmental (altruistic information) and health benefits (egoistic) explains why the highest average bid was received for the liquid smoked chicken breast after the participate discovered both the personal benefit and the environmental benefit of liquid smoke.

Strategies that channel consumers' self-interest are usually more successful especially in Western culture. Moreover, health benefits elicit a premium on products which is often true for health foods (Jo and Lusk 2018). Other potential influence nudging the panelist to bid higher for product is power of self-interest (Miller 1999). An interesting replication of the current auction experiment would be to see if in other cultures, in which, the group's interest is more important than the interest of the individual, would have a larger average mean bid for the environmental benefits than personal health benefits (Hofstede 2011). Another study highlighted that the most powerful advertising are marketing strategies that incorporates both egoistic and altruistic information for the consumer and tend to achieve the highest premium compared to other products which did not used both types of information (Kareklas et al. 2014). Essentially, the combined statements describing the liquid smoke environmental (altruistic information) and health benefits (egoistic) explains why the highest average bid was received for the liquid smoked chicken breast after the participant discovered both the personal benefit and the environmental benefit of liquid smoke.

As discussed earlier, liquid smoke's aroma and flavor is related to "meaty and savory" notes may play an increasing role as more plant-based foods are established in the retail marketplace. Research documenting Umami has basic taste is well documented elicited from two amino acids— the ubiquitous monosodium glutamate MSG) and aspartate. While controversy remains if umami has satiety effects, umami has been studied as a taste that linked to savory notes which have satiety effects and appetite suppression. (Fuke and Ueda 1996; Chandrashekar et al. 2006; McCabe and Rolls 2007). The potential interplay between the umami taste and liquid smoke becomes even more important as the plant-based companies seek to expand their consumer based and improve their customer's experience.

Moreover, optimizing foods for satiety effect is a multimodal approach including aroma, taste and mouthfeel (Chambers et al. 2015). (Havermans et al. 2010) suggests that the combination of aroma and taste induced a greater short-term satiety than the independent aroma or taste alone. Furthermore, (Havermans et al. 2009) explains sensory-specific satiety can be viewed as decline in pleasure from a food when compared to other unconsumed food; the effects of sensory-specific satiety are temporary. Meanwhile a variation of foods can cause an increase in appetite (Snoek et al. 2004). Her research demonstrated that high protein food with low taste variety will often help a person achieve the highest sensory-specific satiety. She further argues that a less variety patient diet is needed to help the patient needing to lose weight through sensory specific satiety effects which will help decrease the overall calories consumed by the patient. Theoretically a high protein diet of similar flavored smoked foods could be beneficial for weight loss.

4. Conclusion

In conclusion, a non-hypothetical auction was conducted to investigate the effects of formatting information about a common yet still somewhat novel food ingredient, liquid smoke. This study aimed through an experimental N^{th} price auction to understand how consumers' willingness to pay is influenced through either a better understanding of the environmental or health benefits of liquid smoke. The final round of bidding showed the effects of both information on the consumer which resulted in the highest average bid price for the liquid smoke chicken. In WTP studies by sensory scientists, statements describing both health benefit to the consumer as well as environmental impact of ingredients, manufacturing or raising process will increase their WTP substantially.

Conflict of Interest: The authors declare no competing financial interest.

Funding and support: The Authors acknowledge support from a liquid smoke manufacturer who provided financial support for this study.

Ethics Statement: This study was reviewed and approved by the University of Arkansas Institutional Review Board, IRB #: 1806126303.

Data Availability: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Table 1a. Script of health benefits of using liquid smoke, read to each group of panelists.

Cooking food at high temperatures causes charring of the foods resulting in the formation of polycyclic aromatic hydrocarbons, PAH. PAH is a term used to describe a group of chemicals which have been linked to initiating cancer. PAH are formed during grilling, roasting or smoking chicken by the incomplete combustion (pyrolysis) of organic materials (like wood). Conventionally smoked chicken are at a greater risk of having a higher concentrations of PAHs on average than chicken that are prepared at lower temperatures using natural condensed liquid smoke.

Table 1b. Script of technological / environmental benefits of using liquid smoke, read to each group of panelists.

Natural condensed liquid smoke is formed by burning hickory wood and condensing the smoke in a cold-water spray at low temperatures. The condensed liquid smoke is filtered to remove impurities before bottling. Using liquid smoke in foods helps decrease cooking time while producing similar conventional wood smoked flavor. Liquid smoke is also estimated to have a lower environmental impact than the conventional smoking process.

Table 2. Impact on Willingness to Pay bids by order of presentation of formatting materials.

	Treatment A			*Treatment B*		
	Mean	Median	Std. Dev	Mean	Median	Std. Dev
*Round 1**	$0.83**	$0.08	$1.25	$0.64	$0.00	$1.08
Round 2	$1.13	$0.50	$1.55	$0.82	$0.50	$1.10
Round 3	$1.28	$1.00	$1.53	$0.96	$0.50	$1.30

*Round 1 Panelist tasted product for both treatments, no information effects
Round 2 Panelist tasted product for both treatments. Treatment A information effect is Health, Treatment B is Environment
Round 3 Panelist tasted products for both treatments. Treatment A information effect is Health + Environment and Treatment B's information effect is Environment + Health formatting information
**There were no significant differences from the treatments, order of presentation of the formatting materials, between the two panels. There were no significant differences comparing no information, Round 1 to either of the information treatments in Rounds 2 and 3.

Table 3. Effect of Information and order of information.

Information Treatment	*Information Effect*	*Value Change*	*Mean*	*P-Value*	*Std. Dev*
Treatment A N= 54	Health	R2-R1	0.31	0.004* (0.000*)	0.10
	Environment	R3-R2	0.14	0.106 (0.003*)	0.09
	Health + Environment	R3-R1	0.45	<0.000* (<0.000*)	0.10
Treatment B N=58	Environment	R2-R1	0.18	0.002* (0.002*)	0.06
	Health	R3-R2	0.14	0.222 (0.017*)	0.11
	Environment + Health	R3-R1	0.32	0.024* (0.000*)	0.14

* Significance value of α=0.05, Two-tail Paired T-Test (Wilcoxon signed ranked non-parametric test)

Table 4. Panelist Demographics

Demographics	Categories	Treatment A Mean	Treatment A Std Dev.	Treatment B Mean	Treatment B Std Dev.	P-Value
Gender	1: Female, 0:Male	0.46	0.50	0.41	0.50	0.60
Age	Years	38.28	14.46	40.19	14.39	0.48
Income	Under $15,000-$39,999	57%		62%		
	$40,000-$79,999	26%		26%		
	$80,000- More than $100,000	17%		12%		0.97
Ethnicity	American Indian or Alaskan Native	0%		5%		
	Asian/Pacific Islander	9%		5%		
	Black or African American	9%		5%		
	Hispanic	2%		7%		
	White/Caucasian	80%		78%		
	Other	0%		0%		0.76

Table 5. Food spending habits and meal preparation times between panelists 1) Results expressed on a Likert scale where 1 represented spending less than $60 / week on food both at home and away and 5 represented spending more than $150 / week for food. 2) Results on Likert scale where 1 was less than 20 minutes / day for meal preparation and 5 more than 80 minutes / day.

		Treatment A			*Treatment B*				
Habits	Categories	Mean	Median	St Dev.	Mean	Median	Std Dev.	T statistic	P value
Approximately how much does your household spend on food consumed at home and away from home during a typical week?	5:More than $150 per week 1:Less than $60 per week	2.41	2	1.17	2.48	2.00	1.20	-0.34	0.74
How many people live in your household?	6: 6, 1: 1	2.48	2	1.27	2.50	2.00	1.26	-0.08	0.94
Approximately how much time do your household spend on average per day in meal preparation	5: More than 80 minutes per day, 1: Less than 20 minutes per day	2.28	2	0.68	1.05	2.00	0.76	-0.24	0.81

Table 6. Frequency of selected muscle meat consumed between panelists. Results expressed on a Likert scale where 1 represented never consumed and 5 at least once a week consumed.

	Frequency of Selected Muscle Meat Consumed	**Treatment A**		**Treatment B**			
	Categories	Mean	St Dev.	Mean	Std Dev.	T statistic	P value
Ground Beef/hamburger	5: At least once a week, 1: Never	4.19	1.20	4.34	0.98	-0.77	0.44
Steak	5: At least once a week, 1: Never	3.26	1.07	3.26	0.93	0.00	1.00
Chicken	5: At least once a week, 1: Never	4.69	0.80	4.83	0.50	-1.12	0.26
Pork	5: At least once a week, 1: Never	3.67	1.32	3.66	0.95	0.05	0.96
Fish	5: At least once a week, 1: Never	3.50	1.30	3.38	1.34	0.48	0.63

Table 7. * Significance value of α=0.05, t-Test: Paired Two Sample for Means. Pre-treatment survey.

		Treatment A			Treatment B				
Questions	Categories	Mean	Median	St Dev.	Mean	Std Dev.	Median	T statistic	P value
How important are the health benefits of foods to you?	5: Extremely important, 1: Not at all important	3.83	4.00	0.84	3.88	0.80	4.00	-0.30	0.77
How important is understanding of how your food is produce to you?	5: Extremely important, 1: Not at all important	3.52	3.50	0.77	3.48	1.00	4.00	0.21	0.83
How important is a “all-natural” food label claim to you?	5: Extremely important, 1: Not at all important	2.93	3.00	1.06	2.76	1.01	3.00	0.37	0.71
How important is the environmental impact of your food	5: Extremely important, 1: Not at all important	3.37	3.00	1.00	3.34	0.97	4.00	0.14	0.89
On a scale from 1 to 5, please rate your familiarity with condensed natural wood smoke (liquid smoke)	5: Very familiar, 1: Very unfamiliar	2.57	2.00	1.27	2.48	1.37	2.00	0.37	0.71
On a scale from 1 to 5, please rate your level of acceptance of using liquid smoke in food production	5: Very familiar, 1: Very unfamiliar	3.30	3.00	0.96	3.57	1.04	3.00	-1.44	0.15

Table 8. * Significance value of α=0.05, t-Test: Paired Two Sample for Means. Post-treatment survey.

		Treatment A		Treatment B			
Questions	Categories	Mean	St Dev.	Mean	Std Dev.	T statistic	P value
Did you know how liquid smoke was made before the auction?	1: Yes, 0: No	0.09	0.29	0.16	0.37	-1.00	0.32
Did you know about the health impact of smoked foods before this auction?	1: Yes, 0: No	0.17	0.38	0.19	0.40	-0.32	0.75
Did you know about the environmental benefit of liquid smoke before this auction	1: Yes, 0: No	0.04	0.19	0.05	0.22	-0.38	0.71
How often do you eat foods that you would want to have a smoky flavor?	5: Daily, 1: Once every few month	1.19	0.73	1.05	0.76	0.95	0.34

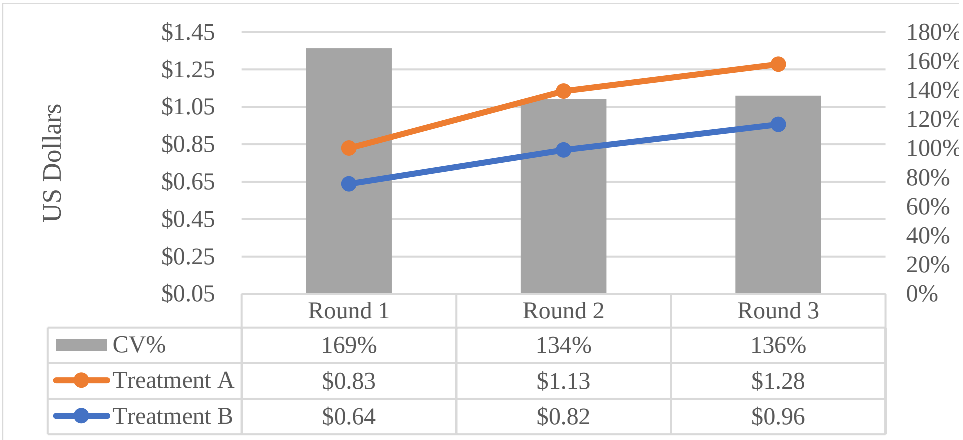
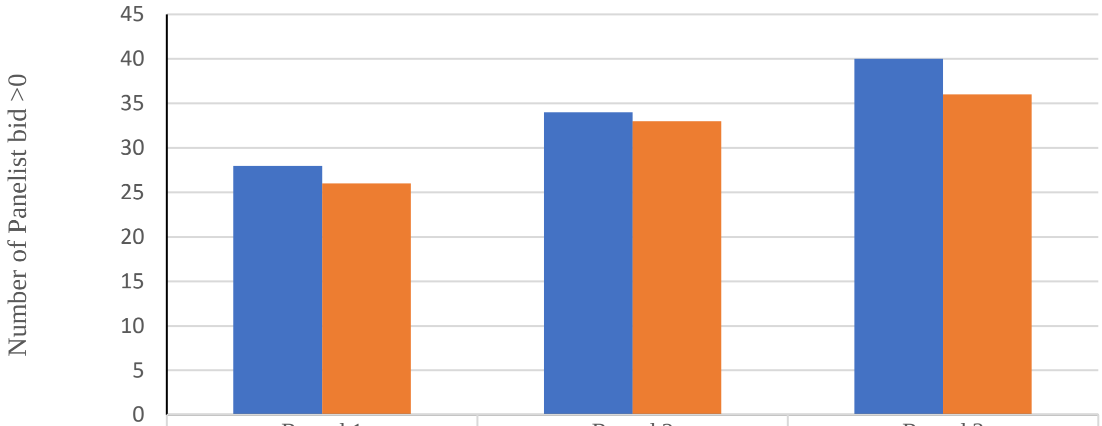


Figure 1. Mean bid per Round by Treatment. Health information had larger impact on the mean bid price but not a signifcant difference between treatment groups.Round 1 Panelist tasted product for both treatments, no information effects. Round 2 Panelist tasted product for both treatments. Treatment A information effect is Health, Treatment B is Environmental formating statements. Round 3 Panelist tasted products for both treatments. Treatment A information effect is Health + Environment and Treatment B's information effect is Environment + Health formating statements. Not shown in this graph is the trend for participant to bid on the liquid smoke chicken as a result of the formatting information effects during either treatment. Both treatment had a positive trend in the bid price as more panelist learned more about the benefits of liquid smoke chicken health or environmental wise.



	Round 1	Round 2	Round 3
Treatment A	28	34	40
Treatment B	26	33	36

Figure 2. Panelist engagement, those who bid more than zero.* The number of panelists from A and B steadily increased as additional formating information was provided. This figure gives the numbers of panelists actively bidding in each round. This was expected from privious N^{th} style auctions so the Torbit model was run to minimize the impact of these zero value, no bids. We considered only analizing the bids above zero in each Round, but this was discarded because there was no way to know which panelist initially bid zero then participated in later rounds of bidding after listening to the formating messages.

*Treatment A had 54 panelists and Treament had 58 total panelists after removing incomplete data collection.

	Pooled
	Coefficient (Std. Err.)
Treatment	0.82 (0.38)***
All_Natural_Food	-0.20 (0.07)**
Eat_Foods_Smokey	1.15 (0.18)***
People_Household	0.05 (0.06)
Time_Household	-0.01 (0.09)
Age	0.011 (0.005)
Income	0.14 (0.03)***
Intercept	-1.02 (0.39)**
N. of Obs	333
Log likelihood	0.61 (0.04)***

Figure 3. Panel demographics impact on willingness to pay

Figure 3 . *,**,*** denote significant levels at 10%, 5%, and 1%, respectively. Treatment A and Treatment B had colinearly in the model (shows treatment has effect and confirms no difference between the order). After performing a Tobit left censored analysis in R using the cenRegs Package (Henningsen) and obtaining starting values through the Wallace-Hussian estimator panel model, treatment (i.e information presented to the participates), the frequency of consuming smoked foods, and income were significant explanatory variables that can be used to help predict the bid premium of a panelist. The more likely someone to eat smoked foods or have a higher income would predict an increase in a person's willingness to pay. Likewise, the more formatting information a consumer learned about liquid smoke the higher the premium the consumer would be willing pay to purchase a food product with liquid smoke in it.

Thesis Conclusion

The applications for mesquite trees and their products are nearly limitless, but how to manage mesquite tree's invasion of lands still eludes researchers and government agencies alike. Mesquite tress were once heralded as the salvation of arid land as result of the Prosopis species' ability to fix nitrogen, enriching the soil; however, governments latter realized the water demand of mesquite tree outweighed its benefits. The uses of mesquites trees included food for human or animal consumption, lumber, biofuel, and an emerging application as an organic bio-filter. However, humans mixed relationships with mesquite uses from different economical functions in society compound the problem to effectively control mesquite afflicted lands. As discussed, ample supply of mesquite biomass material exists from mesquite tress which the food industry can leverage to improve their product via the conversation of biomass mesquite material to liquid smoke. The presented a non-hypothetical auction demonstrated formatting information about a common yet still somewhat novel food ingredient, liquid smoke, can increase the demand and price for liquid smoked food products. The experimental Nth price auction was used to explain how consumers' willingness to pay is influenced through either a better understanding of the environmental or health benefits of liquid smoke. The final round of bidding showed the effects of both information on the consumer which resulted in the highest average bid price for the liquid smoke chicken. Additional research should be conducted to explore other ways to increase consumers' willingness to pay for liquid smoked products. Increased demand for liquid smoke products will in turn provide a larger commodity market for mesquite biomass, thus providing additional incentives for land managers to more aggressive harvest the invasion mesquite tree from public land.

Appendix

UNIVERSITY OF ARKANSAS

To:	Philip G Crandall FDSC N-213
From:	Douglas James Adams, Chair IRB Committee
Date:	08/02/2018
Action:	**Expedited Approval**
Action Date:	08/02/2018
Protocol #:	1806126303
Study Title:	Random Nth price auction with Liquid Smoke: How technology and health benefits for a novel food product influence consumers' willingness to pay
Expiration Date:	06/17/2019
Last Approval Date:	

The above-referenced protocol has been approved following expedited review by the IRB Committee that oversees research with human subjects.

If the research involves collaboration with another institution then the research cannot commence until the Committee receives written notification of approval from the collaborating institution's IRB.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date.

Protocols are approved for a maximum period of one year. You may not continue any research activity beyond the expiration date without Committee approval. Please submit continuation requests early enough to allow sufficient time for review. Failure to receive approval for continuation before the expiration date will result in the automatic suspension of the approval of this protocol. Information collected following suspension is unapproved research and cannot be reported or published as research data. If you do not wish continued approval, please notify the Committee of the study closure.

Adverse Events: Any serious or unexpected adverse event must be reported to the IRB Committee within 48 hours. All other adverse events should be reported within 10 working days.

Amendments: If you wish to change any aspect of this study, such as the procedures, the consent forms, study personnel, or number of participants, please submit an amendment to the IRB. All changes must be approved by the IRB Committee before they can be initiated.

You must maintain a research file for at least 3 years after completion of the study. This file should include all correspondence with the IRB Committee, original signed consent forms, and study data.

cc: Seth W Ellsworth, Investigator
Han-Seok Seo, Investigator

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