Consumer Acceptability of Plant-Based [KAB1]Chickpea Hummus with Naturally Derived Sodium Reducers

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Approval

Consumer Acceptability of Plant-Based Chickpea Hummus with Naturally Derived Sodium Reducers

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Dedication

This thesis work is dedicated to my husband and my son. Your unwavering support and encouragement along the way kept me strong. This work is also dedicated to my mother and brother. Your words of encouragement along with sage advice and insights kept me grounded. Lastly, this thesis is dedicated to my family and friends along the way who encouraged me and let me talk ad nauseum about my research with hummus. My appreciation is endless.

Dedicated in memoriam to Sr Leona Truchan SSSF, Sr Joel Read SSSF, Sr Austin Doherty SSSF, my mother-in-law, and great aunt. This quintet of amazing women brought joy and inspiration to my life. Their endless patience and encouragement to always ask questions and seek answers has made this journey in food science such adventure. When the world is your classroom, you will always be learning.

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Abstract

This study focused on FDA guidance on reducing sodium by 40% in plant-based chickpea hummus by using naturally derived sodium reducers and whether it would be deemed acceptable by the general consumer. Three variations of hummus were given to a general consumer panel comprised of Mount Mary University students, faculty, and staff along with the general public. The panel was asked their overall opinion about the three samples and then ranked the samples. Results showed that reducing the sodium level in hummus by 40% along with using a natural derived sodium reducer was achievable and found to be acceptable to the general consumer. Future research on this topic could include the use of other treatments to reduce pathogenic outgrowth such as roasting the chickpeas or using high pressure pasteurization (HPP). Other treatments could include the use of herbs and spices to improve flavor or adjusting the level of other known sodium reducing agents.

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[KAB2]

Chapter I: Introduction

Plant-based foods and cleaner food labeling has led the general consumer to make healthier and more conscientious food choices. As more and more options become available in the retail marketplace, plant-based foods are gaining prominence. Chickpeas and tofu (soybeans) are two plant-based items that consumers are incorporating into their diets. Plant-based ingredients like chickpeas are key components that are being used by food manufacturers to meet this demand. As the consumer understands more about plant-based proteins and food products, their palate has also changed.

The Food and Drug Administration (FDA[KAB3]) published a guidance document in October 2021 that outlined the agency's plans to reduce the levels of sodium in the typical American diet. The average daily sodium consumption for an American aged 14 and older is 3,400mg (FDA, 2021). For this same group, the recommended daily allowance (RDA) for sodium is 2,300mg (FDA, 2021). As part of the guidance outcomes, the FDA identified a short-term goal of 12% sodium reduction over the next 2.5 years and a long-term goal of 40% over the next decade (FDA, 2021).

Chickpea hummus is a popular ready-to-eat (RTE) dip consumed by the general population. The USDA nutritional database lists the amount of sodium in 100g of chickpea hummus to be approximately 375mg or 16% of RDA (Wallace et al, 2016) and the amount of sodium in various commercial hummus products can be just as high or even higher. Hummus is a nutrient dense dip that has many health benefits. Regular consumers of hummus tend to have higher nutrient intakes of dietary fiber, various vitamins, magnesium, iron, and potassium. See Table 1 in Appendix A for full nutritional panel (Wallace et al, 2016).

The purpose of this study was to determine consumer acceptance of plant-based sodium reducing ingredients when used in a known product in the marketplace (chickpea hummus). By reducing the sodium level by 40% using novel plant-based sodium reducing ingredients, food manufacturers will have healthier alternatives than commonly used traditional sodium agents. The null hypothesis was that the samples do not differ in sodium content and overall acceptability. The alternate hypothesis was that the samples differ in both sodium content and acceptability.

A 68-person consumer panel from the general community (including the MMU community) was asked their opinion and preference level regarding the three types of chickpea hummus (control, Evora™ S40 at 0.75% and 1.25%) with varying sodium levels. Each hummus type, except the control, contained a naturally derived sodium replacer that did not add additional sodium, but gave the impression of the presence of sodium. The panel was asked to rate the aspects of texture, flavor, appearance, and overall likeability. Results from the panel were shared with the ingredient manufacturer, Third Wave Bioactives®.

The study had three specific Aims. Aim 1 was to create a recipe for plant-based chickpea hummus that reduced the sodium content by 40% using a naturally derived sodium reducing ingredient (Evora™ S40) that were acceptable to seven food industry peers. Aim 2 was based on Aim 1 findings, test versions for texture, pH, water activity, spoilage, and microbial pathogens (*Salmonella*, *Listeria*, Lactic acid bacteria, and *Coliform/ E.coli)* to verify that items are safe for human consumption. Aim 3 determined overall consumer perception of sodium by using the control (traditional hummus) and two Evora™ S40 versions from Aim 1.

Chapter 2: Literature Review

Elevated sodium levels in the typical American diet have been attributed to how the food is processed, packaged, and prepared. Sodium can be found in preservatives, flavor/texture enhancers, and extenders that are used by food manufacturers in their formulations. The elevated sodium level is not from the general consumer just adding table salt alone (FDA, 2021). The addition of sodium in foods has led to lower life expectancy rates (Ma et al, 2022). Over a 9-year period, consumers in the United Kingdom (UK) were asked to provide feedback on salt usage and food consumption through a voluntary study. The addition of more salt in with the already salty food led to higher death rates around the age of 50 for both men and women. Consuming large amounts of vegetables and fruit that were high in potassium reduced the risk for this same group. The limitations of the UK study were that total sodium intake was not able to be quantified.

Frankenfeld et al, 2020 conducted a similar study using data from a US survey given over a 10-year period that focused on hummus and chickpea consumers. Typical consumers were more likely to be female, 19-35 years old, with a higher income. Consumers with lower incomes were able to afford hummus as it was found to be an affordable option, even with limitations and costs associated with accessing fruits and vegetables (Frakenfeld et al, 2020). Typical overall hummus consumption was daily, usually with lunch, dinner, or as a snack. Hummus consumers tended to eat more vegetables and fruits when compared to non-consumers. The average American consumer does not eat enough vegetables despite the established and known benefits of doing so (Wallace et al, 2016).

Hummus was described as an emulsified encapsulated microstructure containing chickpea paste, tahini, and lemon juice (Ahmed et al, 2020). Cross contamination from mixing ingredients, improperly cleaned equipment, and improper handling have led to outbreaks that required product to be recalled due to the presence of *Salmonella, Listeria,* and *E. coli* (Olaimat et al, 2022, Salazar et al, 2022). Typical preservatives such as potassium sorbate, garlic extract, and essential oils have been effectively used to control pathogenic outgrowth. Established methods such as high-pressure pasteurization (HPP) can effectively prolong the product's shelf life without the addition of preservatives (Ahmed et al, 2020). The HPP study tested the hummus samples pre and post treatment for moisture 60.59, pH 5.48, total soluble solids (TSS) as brix 16.4 (Ahmed et al, 2020). Yamani and Mehyar in 2011 found that when potassium sorbate was added to hummus stored at 5°C, it lasted longer than 90 days. Sodium metabisulfite and sodium benzoate were most effective when used together (Yamani and Mehyar, 2011). Lactic acid bacteria (LAB) had the highest counts when control hummus (no preservative) was tested for spoilage when stored at 5°C. Hummus formulated with a pH lower than 5 was shown to improve the effectiveness of the preservatives.

Salazar et al, 2020 studied *Listeria monocytogenes* in ready-to-eat (RTE) dips (including hummus and tahini) to see how the pathogen grew and responded in cold storage conditions. The study allowed for better formulation and risk analysis of cold storage specifically for this pathogen. The hummus dip tested in the study had a pH of 5.12 and water activity (Aw) of 0.987, which are typical for RTE dips requiring refrigeration. The study also investigated slightly warmer storage temperatures of 10°C and 15°C and the ability to enable further growth.

Chickpeas have a nut like flavor and are versatile when it comes to sensory applications (Wallace et al, 2016). Texture is one of the best sensory attributes comprising visual and tactile stimuli and influences the consumers liking or disliking towards a food. (Ahmed et al, 2020). Processing of chickpeas allows for easier digestibility but overprocessing may lead to destruction of functional ingredients and edible value (Wang et al, 2021). Commercial processing may alter the taste profile and nutrient availability of hummus (Wang et al, 2021). Small reductions of sodium in food (less than 10%) are not typically noticed by the general consumer (FDA, 2021).

Use of plant-based ingredients in food manufacturing has increased over the past five years. Lowering the sodium level in foods by use of addition of herbs, spices, and herb blends were found to be acceptable when the sodium level was reduced by >50%. Herb consumption in food exerts a hypolipidemic effect along with lowering blood pressure (Farkhondeh et al, 2019). Though there are many advantages about using plant-based ingredients, concerns about product safety were raised as lowering sodium in food may allow for the potential of microbial outgrowth (Lorén et al, 2023). Use of a plant-based preservative such as Nisin was advised to reduce the potential outgrowth (Benerroum and Sandine, 1988 and Taladrid et al, 2020).

Previous research done on the subject focused on chickpea hummus that was treated with preservatives, water pressure by means of HPP, or had pathogens added to test shelf-life and storage parameters (Yamani and Mehyar, 2011, Ahmed et al, 2020, Salazar et al, 2020). Salt and sodium levels were not recorded as part of research parameters. Aside from purchasing the hummus, a few studies used dry chickpeas that were soaked overnight (Ahmed et al, 2020, Salazar et al, 2020). None of the research used canned low sodium chickpeas, discussed rinsing the chickpeas, or used a plant-based sodium reducing agent. The FDA guidance document does not reference how to reduce levels or what can be used to reduce the levels beyond sodium reducers and rinsing canned vegetables (Duyff et all, 2011).

To date, there has been one published study by Dunteman and Lee, 2023 that looked at the effects of reducing sodium by using monosodium glutamate (MSG) in various bread types. The study looked at the overall consumer acceptance of white and multigrain breads with reduced sodium using MSG as a sodium replacer (Dunteman and Lee, 2023). Study found that the breads with different treatments in sodium and MSG when compared to full sodium breads were similarly liked by the panel. Future research suggested MSG as a viable sodium replacer, and not just for flavoring.

In conclusion, a wide range of research has been done already on chickpea hummus. A sodium reduction study on white bread and MSG showing promise for future research in this area. Limited information was found that discussed canned low sodium chickpeas, rinsing the chickpeas, or use of a plant-based sodium reducing agent to reduce sodium. A 40% sodium reduction goal in 10 years by the FDA in the typical American diet would lead to further health benefits and extended the life span for both men and women by a few years (Frankenfeld et al, 2020, FDA, 2021, Ma et al, 2022). Research provided key insight to pathogens and spoilage organisms to most likely to be present in the chickpea hummus were *Salmonella, Listeria,* Lactic acid bacteria, and *Coliforms/ E. coli* (Yamani and Mehyar, 2011, Ahmed et al, 2020, Salazar et al, 2020). Storing chickpea hummus at 5°C, using plant-based preservatives, and testing for key food safety parameters (pH, water activity, moisture) allows for the potential risk of pathogen outgrowth to be reduced (Lorén et al, 2023).

Chapter 3: Materials and Methods

Materials and Equipment: The ingredients for the research (chickpeas, garlic, lemon juice, tahini, and salt) were purchased from a local retail establishment. Retail purchased items were ready to consume, shelf stable, in hermetically sealed containers (chickpeas, garlic, salt, and tahini) and/or pasteurized (lemon juice). Naturally derived sodium reducer ingredient Evora™ S40 along with Nisin preparation (plant-based preservative) were supplied by Third Wave Bioactives™ and came sealed. De-ionized (DI) water was supplied by Mount Mary University. Plastic consumables such as vacuum seal bags, 2-ounce containers, 2-ounce lids, and taster spoons were purchased through a local food packaging supplier. Blenders used in the study were Vitamix (Vitamix, Olmsted Township, OH, USA) and Waring (Conair Corporation, Stamford CT, USA). Chemical analytical testing was done using an in-house pH meter, salt meter, moisture meter, and water activity meter (equipment provided by Mount Mary University). Nutritional informational panel (NIP) and sodium values were calculated using a web based free nutritional panel calculator. Consistency and texture were analyzed by use of a Bostwick Consistometer for 30 seconds along with visual organoleptic analysis (color, flavor, texture). Hummus that was made for consumption by the general panel was tested for spoilage bacterium and pathogenic microbials *(Coliform/ E. coli,* Lactic acid bacteria*, Listeria,* and *Salmonella*) using 3M Petrifilm (3M, Minneapolis, MN, USA), and Alpha enrichment broth and media (Alpha Biosciences, Baltimore MD, USA) and Bio-Rad RAPID'*L.Mono* Chromogenic plates (Bio-Rad Laboratories, Hercules, CA, USA). Seven food industry peers and sixty-eight members from the general community (including MMU) were asked to participate in a sensory panel. RedJade sensory testing software (RedJade Sensory Solutions, LLC, Martinez, CA, USA) was used to collect and analyze sensory data from the panelists and provided charts. Mount Mary University (Milwaukee, WI USA) provided the space and equipment (lab equipment, blenders, stove, scales, and utensils) to prepare the materials along with a dedicated area for sensory testing.

Naturally derived ingredients Evora™ S40 and Nisin preparation: Evora™ S40 has clean umami notes and is used to boost and enhance saltiness, which makes it ideal for use in this sodium reduction study. Typical use is 0.5% to 1.5% based on overall formulation percentage of product. The provided range is a starting point, which is modified during sensory to ensure that the flavor profile is acceptable per product. Third Wave Bioactives d[KAB4]etermined the usage rate based on similar products that are currently used in the marketplace. Evora™ S40 was made using traditional fermentation process and dried into a tan powder. This ingredient does not contain any of the 9 US allergens. Made in the United States, the ingredient is Kosher and Halal Certified.

Nisin preparation is a blend of antimicrobial polypeptide nisin (E234) and sodium chloride (not adding additional salt), isolated from fermented strains of *Lactococcus latics,* and dried into a light tan powder. Nisin was used to inhibit potential pathogenic microbial outgrowth and bactericidal against spore forming by disintegration of the cell membrane. Nisin preparation as a treatment was used in all batches of hummus made in Aim 3 at the rate of 400ppm, based on FDA guidelines. This ingredient does not contain any of the 9 US allergens and is FDA approved and GRAS (generally regarded as safe) for use in food products as a preservative.

Hummus Recipe: The recipe used for all six hummus types was based on a family recipe. Aim 1 had six prototype versions that yielded approximately 18 ounces per type made. Differences in the six versions were the levels of Evora™ S40 and amount of added salt. Aim 1 recipes can be found in Table 2 in Appendix A. Aim 3 versions yielded approximately 127 ounces per type made. Differences in the three variations are the levels of Evora™ S40 and amount of added salt. Aim 3 formulations can be found in Table 3 in Appendix A.

Sensory Panel: Two sensory panels were conducted for this research study using RedJade sensory testing software. See Appendix B and C along with the results section for panel particulars and question insights. Results were tallied and the three versions that had the most overall acceptance were scaled up for Aim 3. Overall acceptance of any sample in Aim 3 will be deemed "most preferred" by the general consumer.

RedJade Software**:** RedJade is a software as a solution (SaaS) sensory analysis tool that was used to gain insight to consumer perception. For both the initial and general consumer panels, a RedJade survey gauged perception of the chickpea hummus as a control versus the two hummus types that contained plant-based sodium reducers. See Tables 6 through 9 in Appendix B for the full survey.

Questions regarding dietary food preference and plant-based purchase habits were given for demographics along with another exclusion questions including pregnancy and loss of taste due to illness. A hedonic scale (most to least preferred) to gauge liking or disliking of each hummus to flavor, texture, mouthfeel, and then overall perception was captured for analysis. Examples of the survey questions used can be found in tables six through nine in Appendix B. Comments about each attribute were sought post tasting. At the end of the survey, panelists were asked to pick a single hummus type that was the most preferred along with an inquiry on purchase intent. Data collected was also analyzed using RedJade, which allowed for the data points to be measured showing data trends and relevant insight including statistical significance and correlations.

IRB Approval: Due to the use of human subjects in the proposed study, approval was required from Mount Mary University. The entire study proposal and RedJade survey along with IRB application was submitted and approved prior to research being conducted. Approval was granted and research commenced.

Methods

Aim 1 Methods: For Aim 1, six variations of chickpea hummus were prepared using a traditional recipe (see Table 3 in Appendix A). All versions contained chickpeas, lemon juice, tahini, ground garlic powder, and water. Control A was the original recipe with the chickpeas rinsed and used DI water from the MMU food lab. Control B was a high salt version of the control and chickpeas were not rinsed. For both controls, table salt was used. Traditional chickpea hummus was used as a control as this is the hummus that the general population is familiar with.

Versions C through F contained Evora™ S40 (sodium reducer) at various percentages (0.75%, 1%, 1.25%, and 1.5%). Evora™ S40 was added to lemon juice and mixed, per manufacturer direction. Each variation was blended separately using a Vitamix mixer until the desired consistency was met. Post blend, all six hummus types were tested for organoleptic (overall taste and flavor), pH, moisture, and water activity with data recorded. Data captured for the six variations ensured that the ingredients were properly blended and food safety parameters were met (See Table 4 in Appendix A). Data recorded for all testing was used as a baseline for Aim 2 testing. Post texture testing, materials were sealed and stored at 5°C until arrangements with the seven food industry peers were made for the panel to give input. Food industry peers were preferred over food science students as peers had innate knowledge and experience with the Evora™ S40 and understood product development. Prior to the tasting, the six hummus types were brought out to acclimate to room temperature for 15 minutes.

Prior to the initial sensory evaluation, seven food industry peers were screened to ensure that no one was allergic or had a sensitivity to any of the ingredients including sesame (tahini), had not recently smoked, or had lost their sense of taste due to illness. Using the software prompts, samples were given one at a time and then compared. Food industry peers that have worked and are familiar with typical product formulation testing were asked to sample all six variations in sets of 2 (A and B, C and D, E and F) and then chose the version that they preferred terms of overall saltiness, texture, and acceptability using RedJade survey prompts (see Appendix B for complete survey). Participants were also given the option of no preference for the variation sets. Results were tallied and the three versions that had overall acceptance were scaled up for Aim 2.

Aim 2 Methods: Using Aim 1 findings, the three selected versions of the chickpea hummus recipe were made and tested as described by the methods outlined in Aim 1. Using a Waring blender, hummus was blended at medium speed for approximately 45 seconds. Per the blender manufacturer recommendation, liquid ingredients were added first, then chickpeas, then Nisin. Nisin was added as a preservative to all hummus batches made. Aim 2 included microbial testing for spoilage and pathogens in order for the product to be released. The recipe amount was scaled up to approximately 127 ounces so that enough product was made for product testing and sensory panel can be completed. 100 ounces per version was needed for sensory panel as one ounce is the typical serving size. While awaiting pathogen test results, the prepared versions for sensory panels were vacuum sealed with the batch code (B, C, or F) and date prepared written on the bag in permanent marker. Sealed bags were placed in MMU Food Lab refrigerator at 3°C. Approximately 50g to 100g of product was utilized for food safety parameter and pathogen testing. Food safety parameter testing used the same specifications as written in Aim 1 (See Table 4 in Appendix A).

Spoilage and pathogen testing methods were all Association of Official Analytical Chemists (AOAC) or Food and Drug Administration Bacteriological Analytical Manual (FDA BAM) approved methods. *E. Coli/Coliform* and *Lactic Acid* were plated separately per version made using 3M Petrifilm per manufacturer's instructions along with a control plate. Both *Salmonella SALX* and *Listeria* utilized separate enrichment broths. After the amount of sample was added, all bottles were homogenized for two minutes and then placed in dedicated separate incubator for the allotted time per test requirements. Post incubation and per version, samples from the bottles were streaked separately onto either 3M Petrifilm SALX gels or on Oxford Media with supplement added along with a control plate per manufacturer instructions. *Listeria* was streaked onto *RAPID'L.Mono* plates per version along with a control plate per manufacturer instructions. 3M Environmental *Listeria* Petrifilm was used as a confirmation test that *Listeria* was not present in any of the samples or equipment. Results for all pathogen testing were recorded post testing. Pictures were taken during the process and of results as evidence of protocol being followed. In order for the three hummus versions to be released for Aim 3, testing required food safety parameters to be met along with negative results for all pathogens. Any of the hummus versions found to not be within specification or reveal a positive result were remade and retested. Control plates were used per test to confirm that the test itself was not contaminated.

Aim 3 Methods: When Aim 2 results were confirmed that all three versions were within specification with negative pathogen results, the three hummus versions were then staged for a 68-person sensory panel. Due to the samples having limited amounts of preservatives, the sensory panel was done within 15 days of testing. One-ounce samples of each version were placed in containers with lids, labeled with proper identifier, and staged in the refrigerator for sensory testing. Prior to the panel, the three hummus types were brought out to acclimate to room temperature for 15 minutes. Over a two-day period, a total of sixty-eight members of the general community (including the MMU community) took part in sensory panels using RedJade software to collect sensory data (see Appendix B for complete survey). Panelists were screened and sought from the general and MMU community by posted posters, email blasts, and word of mouth. Participants were encouraged to sign up for times through Signup Genus with data populated into RedJade but also included whoever showed up to the sensory lab the days of the panel. Prior to the sensory evaluation, panelists were emailed a RedJade survey link that was accessed through a smart phone. An option to participate using a paper copy of the survey was made available. All participants signed (or electronically signed) a consent form noting that this was a research study. Participants were screened to ensure that no one was allergic or had a sensitivity to any of the ingredients including sesame (tahini), had not recently smoked, or had lost their sense of taste due to illness. Persons eliminated from the study were flagged as survey was written with enabled trigger questions to alert the researcher. Asking the questions for a second time to the panelist confirmed that they were sound to participate in the panel. Additional questions about dietary preference and purchasing of plant-based foods were gathered to gain additional insight about the panelists.

Using the guided software prompts, panelists tasted the three types of hummus types in a blind, monadic sequential test, randomized per panelist, in which all samples are presented (one at a time). All samples were tasted using a tasting spoon following RedJade prompts (see Appendix B for complete survey). Chickpea hummus was used as a control as this was the hummus that the general population is familiar with. All hummus variations including those with Evora™ S40 were given and tasted separately. At the end of the test, panelists selected the single hummus version that they preferred overall. Data collected was analyzed using RedJade software, which allowed for the measurement of data points showing trends and relevant insight. Feedback from the panel was shared with Third Wave Bioactives™, the Evora™ S40 ingredient manufacturer**.**

Chapter 4: Results

Aim 1: Objective for Aim 1 was to create a recipe for chickpea hummus that reduced the sodium content by 40% using a naturally derived ingredient (Evora™ S40) that were acceptable to seven food industry peers. All variations were tested for food safety parameters. The values listed are for the three samples that were selected by the panel; High Salt B, Evora™ S40 C (0.75%), and Evora™ S40 F (1.50%). pH for the three hummus samples was < 5; 4.47, 4.61, and 4.92. Water activity readings for the samples were 0.986, 0.993, and 0.992. Nutritional informational panel (NIP) was used to calculate sodium to show amount present in sample as well as the > 40% decrease from control. Sodium NIP for High Salt B was 296 mg. Sodium for S40 C and F was 134mg, a 53% decrease from the control. CEM moisture readings for the samples were 69.37, 65.54, and 66.94. Organoleptic tests for color, flavor, and texture (CFT) were done visually and met criteria for all samples; Hummus like with hints of garlic, lemon, and salt. Dark specs from the tahini were observed to give the hummus a speckled appearance. High Salt B color values were 60.8 (L), 5.8 (a), 21.7 (b). Evora™ S40 C (0.75%) color values were 60.9 (L), 5.5 (a), 20.6 (b). Evora™ S40 F (1.50%) color values were 53.8 (L), 5.3 (a), 19.1 (b). See Table 10 below and Table 11 in Appendix C for full Aim 1 food safety parameter results and Sodium NIP calculations.

Table 10.

Aim 1 Food Safety Parameter results.

All methods are AOAC.	Samples and Evora™ S40 treatment levels (percentage)					
Test	**Control A @ 0%**	**High Salt B @ 0%**	**S40 C @ 0.75%**	**S40 D @ 1.00%**	**S40 E @ 1.25%**	**S40 F @ 1.50%**
pH	4.45	4.47	4.61	4.58	4.61	4.92
Aw	0.992	0.986	0.993	0.989	0.990	0.992
Sodium NIP	153mg rinsed*	296 mg unrinsed	133 mg rinsed*	133 mg rinsed*	133 mg rinsed*	133 mg rinsed*
Moisture	66.94	69.37	65.54	67.46	67.69	66.94
CFT	Meets	Meets	Meets	Meets	Meets, thinner	Meets
Color	L: 51.6 a: 4.6 b: 17.5	L: 60.8 a: 5.8 b: 21.7	L: 60.9 a: 5.5 b: 20.6	L: 55.9 a: 5.2 b: 19.6	L: 55.2 a: 5.1 b: 18.9	L: 53.8 a: 5.3 b: 19.1

*Rinsed with water and allowed to rest for 2 min to remove 40% sodium

Six versions of chickpea hummus were presented in one-ounce containers to seven food industry peers from the ingredient manufacturer. When asked “How often do you consume or purchase plant based foods”, the purchasing habits of the were vast. 33% purchased plant-based foods daily. 31% purchased plant-based foods weekly. 7% purchased plant-based foods every other week. 21% purchased plant-based foods monthly. Only 7% had never purchased or consumed plant-based foods.

None of the results gathered by the panel were statistically significant due to the low number of panelists. High Salt B 0% scored the highest overall in most categories. Evora™ S40 F 1.50% scored the lowest in most categories. When asked about overall liking of the samples using a hedonic scale (1-9, 1=dislike extremely to 9=like extremely), the overall opinion was that high salt B 0% (6.57) and Evora™ S40 C 0.75% (5.43) were liked more than Evora™ S40 F 1.50% (5.29). This was also reflected in the Just About Right (JAR) Saltiness, as the samples were considered not salty enough. In order to be considered salty enough, 80% or higher was needed in the Just About Right for any one sample. See Table 12 Aim 1 Food Industry Panel Results below for full results.

Table 11.

Aim 1 Food Industry Panel Results

	Samples and Evora™ S40 treatment levels					
Count n=7	**Control A @ 0%**	**High Salt B @ 0%**	**S40 C @ 0.75%**	**S40 D @ 1.00%**	**S40 E @ 1.25%**	**S40 F @ 1.50%**
Liking Grid: Aroma	5.86A	6.86A	6.00A	7.00A	5.86A	5.43A
Liking Grid: Appearance	6.43AB	6.71A	6.71A	6.57A	6.00AB	5.29B
Liking Grid: Texture	6.43A	6.71A	6.57A	6.14A	6.00A	5.86A
Liking Grid: Overall Flavor	4.86B	7.14A	5.57AB	6.43AB	5.43AB	5.14B
Liking Grid: Garlic Flavor	5.00A	5.86A	5.14A	5.86A	4.86A	4.57A
Liking Grid: Lemon Flavor	4.71A	5.86A	5.00A	5.71A	4.57A	4.14A
Liking Grid: Aftertaste	4.86A	5.29A	4.71A	**5.57A**	4.43A	4.14A
Overall Opinion	5.29A	**6.57A**	5.43A	6.29A	4.71A	5.29A

Just About Right (JAR) Saltiness

	Samples and Evora™ S40 treatment levels					
	Control A @ 0%	**High Salt B @ 0%**	**S40 C @ 0.75%**	**S40 D @ 1.00%**	**S40 E @ 1.25%**	**S40 F @ 1.50%**
Count	**7**	**7**	**7**	**7**	**7**	**7**
Much Too Salty	0%	0%	0%	0%	0%	0%
Slightly Too Salty	14%	0%	0%	0%	14%	29%
Just About Right	29%	57%	43%	57%	29%	43%
Not Quite Salty Enough	14%	29%	43%	29%	43%	14%
Not At All Salty Enough	43%	14%	14%	14%	14%	14%

When asked to choose between 2 samples, High Salt B was preferred 87% over Control A. Clear division was observed over Evora™ S40 C and Evora™ S40 D, with the no preference votes giving Evora™ S40 C the overall preference at 57%. Division was also observed with Evora™ S40 E and F, with the no preference votes giving Evora™ S40 F the overall preference at 57%. In both instances, the no preference responses were evenly distributed between the samples.

Overall thoughts on all hummus variations sampled by the panel were that aroma and appearance was acceptable but texture and overall flavor needed to be improved. Verbal feedback from the panel led to discussions about Aim 2 versions being reformulated to include sodium as they were formulated without. Salt as added sodium was completely removed as it was originally thought that the Evora™ S40 would be enough (and treated as an either/or variable). NIP calculations showed all versions of S40 showed a 53%, sodium reduction as reflected by the panel stating that the versions were not salty enough. Salt was formulated back into to the batches produced in Aim 2 and NIP (nutritional information panel) was re-calculated to ensure that the level was exactly 40% (See table 11, Appendix C). Panelists selected the three hummus versions of high salt 0%, Evora™ S40 0.75%, and Evora™ S40 1.50% which moved on to Aim 2 (see Figure 2 in Appendix C). One limitation to Aim 1 was the number of panelists were the small sample size n=7 decreased the ability to detect statistical significance of the panel findings. Another limitation was that salt was not added to the Evora™ S40 samples.

Aim 2**:** Based on Aim 1 findings, the three selected versions (B, C, F) were tested for texture, pH, water activity, spoilage and microbial pathogens (*Salmonella*, *Listeria*, Lactic acid bacteria, and *E. coli/Coliform)* to verify that items are safe for human consumption. During production, versions were made as written in the methods section. Nisin was added as a preservative and was found to be the most effective when the pH was between 3 and 4 (Benerroum and Sandine, 1988 and Yamani and Mehyer, 2011). pH for the three hummus samples was <5; 3.73, 3.89, and 4.07. Water activity for the samples were 0.9903, 0.9916, and 0.9935. Nutritional informational panel (NIP) was used to calculate sodium to show amount present in sample as well as the 40% decrease from control. Sodium NIP for control B was 288 mg. Sodium for S40 C and F was 173mg, a 40% decrease from the control. CEM moisture readings for the samples were 65.92, 66.04, and 64.47. Organoleptic tests for color, flavor, and texture (CFT) were done visually and met criteria for all samples; Hummus like with hints of garlic, lemon, and salt. Color readings were taken using a portable colorimeter with all the lights turned on in the color box. Control B color values were 61.4 (L), 6.3 (a), 21.1 (b). Evora™ S40 C (0.75%) color values were 40.4 (L), 4.4 (a), 15.9 (b). Evora™ S40 F (1.50%) color values were 47.7 (L), 3.9 (a), 19.0 (b). See Tables 12 below and in Appendix C for Aim 2 food safety parameter results and Sodium NIP panel.

Table 12.
Aim 2 Food Safety Parameters results

Test	Samples and Evora™ S40 treatment levels (percentage) High Salt B @ 0%	S40 C @ 0.75%	S40 F @ 1.50%
pH	3.73	3.89	4.07
Aw	0.9903	0.9916	0.9935
Sodium NIP	288 mg unrinsed	173 mg rinsed*	173 mg rinsed*
Moisture	65.92	66.04	64.47
CFT	meets	meets	meets
Color	L: 61.4 a: 6.3 b: 21.1	L: 40.4 a: 4.4 b: 15.9	L: 47.7 a: 3.9 b: 19.0

*Rinsed with water and allowed to rest for 2 min to remove 40% sodium

For both S40 versions, the ingredient was added to water instead of lemon juice. This made the ingredient blend into the batch and not amplify flavor of the garlic, tahini, or lemon juice. pH was taken of lemon juice (1.63), aquafaba (chickpea water, 5.94), and tahini (5.64) to ensure that the ingredients were contributing to the lowering of the final pH to being below 5. Bostwick consistometer was used to check overall texture and thickness as well as visual observations on color, texture, flavor. Color was taken of lemon juice and tahini to ensure uniform texture and color were present throughout the batches. NIP calculations were done prior to production to ensure that sodium levels for both S40 treatments would be uniform to achieve the 40% reduction from control B (See table 12 and 13 in Appendix C).

Color analysis showed that both of the Evora™ S40 treated hummus were darker than the control. When hydrated, the Evora™ S40 took on a dark tan color. When the chickpeas were added, the color lightened but not enough to match the control. For this study, color was not felt to be a defining factor as the lights in the sensory lab could be adjusted to mask the dark color and have the samples appear uniform.

Post blending, samples were allocated for Aim 2 micro and Aim 3 sensory testing and placed in fridge. Batches were tested for food safety parameters and were fit for human consumption (See table 14, Appendix C). Texture and consistency of all batches was visually observed to be thicker. Samples that were slated for microbiological testing were moved to the refrigerator for 24 hours. This time period allowed for the Nisin to get to full potential as a preservative and decrease microbial outgrowth (Benerroum and Sandine, 1988).

Samples were prepared, plated, and results interpreted according to manufacturers instructions. For all samples, *Coliform* and *E. coli* plated at a 1: 10 dilution with results of <10 cfu/gram per test. CFU is colony formation unit. Lactic acid bacteria *(*LAB*)* plates were diluted to 1:100 due to previous research findings (Yamani and Mehyar, 2011) having elevated numbers even with preservatives. High Salt 0% results were 1000 cfu/gram. Evora™ S40 C 0.75% was 1100 cfu/gram. Evora™ S40 F 1.50% was 1300 cfu/g. SALX system plates were all negative for *Salmonella*. Oxford media and RAPID'*L.Mono Listeria* plates were all negative for *Listeria.* 3M Environmental Listeria Petrifilm were negative for *Listeria* and done as a secondary confirmation. Pictures of results were taken as all items were within specification and no pathogens were present in either *Salmonella* or *Listeria* plates (See Figure 3, appendix C). Post results, all spent materials were autoclaved. All three versions were deemed fit for human consumption and for use in the Aim 3 sensory panel. See Table 13 for full test results.

Table 13.
Aim 2 Microbial spoilage and pathogen results

			Samples and Evora™ S40 treatment levels (percentage)		
			High Salt B @ 0%	**S40 C @ 0.75%**	**S40 F @ 1.50%**
Test	**Amount/Rate**	**Specification**			
3M Petrifilm Coliform/ E.coli	1:10 dilution	<100	C: <10 cfu/g E: <10 cfu/g	C: <10 cfu/g E: <10 cfu/g	C: <10 cfu/g E: <10 cfu/g
3M Petrifilm Lactic Acid Bacteria	1:100 dilution	<10000	1000 cfu/g	1100 cfu/g	1300 cfu/g
3M Petrifilm Salmonella SALX (media with suppliment)	25g in 225mL (Streak plate from enrichment)	Negative for *Salmonella* spp.	Negative	Negative	Negative
BioRad RapidL'mono Plates	25g in 225mL (Streak plate from enrichment)	Negative for *Listeria* spp.	Negative: No growth on plates.	Negative: No growth on plates.	Negative: No growth on plates.
Listeria (Oxford media with suppliment)	25g in 225mL (Streak plate from enrichment)	Negative for *Listeria monocytogenes*	Negative	Negative	Negative
3M Petrifilm Environmental Listeria	25g in 225mL	Negative for *Listeria* spp.	Negative	Negative	Negative

Aim 3: Determine overall consumer perception of sodium by using the control (traditional hummus) and two Evora™ S40 versions from Aim 1. 68 one-ounce samples per version were placed into pre-labeled cups and kept refrigerated. Fifteen minutes prior to panels starting, samples were allowed to get to room temperature for each round of panels. Sixty-eight panelists sampled the three versions over a two day period. One panelist was excluded due to illness. Paper copies of the survey were made available upon request to those participating in the event that there would be issues with technology or participant preferred paper and pen. Sensory lab was set up using red light to reflect on the samples (see Figure 3 in Appendix C for panel set up). Red light was also used to encourage appetite and allow for the samples to appear uniform as the Evora™ S40 treated versions were darker than the control. RedJade serving counsel was used during the panel to ensure that the right sample was given to the right participant in the right order. Samples were served on plates. Bottled water was given as a palette cleanser. Post testing, the samples along with sample spoons were thrown away.

When asked "How often do you consume or purchase plant-based foods", the purchasing habits of were vast. 33% purchased plant-based foods daily. 31% purchased plant-based foods weekly. 7% purchased plant-based foods every other week. 21% purchased plant-based foods monthly. Only 7% had never purchased or consumed plant-based foods. After tasting the samples, the panelists were then asked "How likely they would you be to purchase a product that contains a plant-based ingredient that reduces sodium?" 21% were much more likely to purchase plant-based products. 54% were more likely. 19% were about the same. 4% were less likely. 1% were much less likely to purchase.

Aftertaste was the only aspect of the panel that was significant with a p-value of 0.025 and confidence level 97.5% respectively. All other aspects along with the overall opinion on the samples were not significant as the p-values ranged from 0.11 to 0.681 using Duncan's GLM ANOVA. The panelists felt that the high salt 0% and Evora™ S40 0.75% had similar traits in terms of aroma, appearance, texture, overall flavor, garlic flavor, and aftertaste. Panelists scored Evora™ S40 0.75 higher in lemon flavor. Evora™ S40 1.50% scored lower across the board. This was also reflected in the Just About Right (JAR) Saltiness, as the samples were considered not salty enough. In order to be considered salty enough, 80% or higher was needed in the Just About Right for any one sample. See Table 14 and Table 15 in Appendix C for full results from the consumer panels.

Table 14.
Consumer Panel Results using the Likert Scale.

	Treatment level of Evora ™ S40		
Count n = 67	**High Salt 0%**	**0.75%**	**1.50%**
Liking Grid: Aroma	6.61A	6.40A	6.55A
Liking Grid: Appearance	7.00A	6.90A	6.72A
Liking Grid: Texture	6.93A	6.97A	6.39A
Liking Grid: Overall Flavor	6.57A	6.69A	6.21A
Liking Grid: Garlic Flavor	6.24A	6.37A	5.93A
Liking Grid: Lemon Flavor	5.87A	6.34A	5.76A
Liking Grid: Aftertaste*	**6.27AB**	**6.30A**	**5.55B**
Overall Opinion	6.51A	6.49A	6.07A

****Statistically significant with a p-value of 0.025 and confidence of 97.5%***

Just About Right (JAR) Saltiness

	Treatment level of Evora ™ S40		
	High Salt 0%	**0.75%**	**1.50%**
Count	**67**	**67**	**67**
Much Too Salty	1%	0%	3%
Slightly Too Salty	7%	10%	16%
Just About Right	66%	52%	54%
Not Quite Salty Enough	22%	36%	25%
Not At All Salty Enough	3%	1%	1%

After all the samples had been tasted, panelists were asked to rank the samples in order from most to least preferred. High Salt 0% and Evora™ S40 C (0.75%) were most preferred as the panelists had equal preference. Evora™ S40 F (1.5%) was the least preferred at 46%. When asked why they ranked these items this way, the top 3 words were flavor (n=39), taste (n=21), and texture (n=21). Panelists used these words repeatedly. See Figure 4 in Appendix C for complete word cloud. Lack of statistical significance difference was observed among the samples (p-value >0.05). Statistics method used for analysis was Friedmans two-way ANOVA. Friedmans ANOVA compares three or more observations on an ordinal outcome across subjects. See Table 15 and Figure 4 in Appendix C for full results.

Table 15
Ranking: Ranking

P-Value:	0.137
Confidence:	86%
Stat Method:	Friedman's Two-way
Significant:	**FALSE**

Samples ranked most (1) to least (3)

	Treatment level of Evora ™ S40		
	High Salt 0%	**0.75%**	**1.50%**
Count (N=)	67	67	67
Rank 1	36%	37%	27%
Rank 2	34%	39%	27%
Rank 3	30%	24%	46%
Rank Sum	**130**	**125**	**147**
Post Hoc			

Equation $$Q = \frac{12}{nk(k+1)}\sum_{j=1}^{k} R_j^2 - 3n(k+1)$$

n=67
k=3
Rj = rank sum
Rj^2 = sum of squared rank sums
Q=Friedmans 2-way rank sum

Chapter 5: Discussion

Changing dietary habits, eating a heart healthy diet, and reducing sodium are not easy to get used to. As a researcher, having a family history of cardiac issues and a parent succumb to an aortic aneurysm led to drastic changes in diet and lifestyle practices. The lifestyle and eating habits that contributed to lower life expectancy rates discussed in the article by Ma et al, 2022 also could be applied to the US population. Reducing sodium in the diet may lead to foods tasting bland due to flavors being removed. When sodium levels are reduced by greater than ten percent, the difference is noted by the general consumer. The FDA even acknowledged this in their guidance document from 2021. In Aim 1, sodium was completely removed with the addition of Evora™ S40 and calculated rates showed the reduction at 53%. This level of reduction in sodium led to bitter, astringent, and other unfavorable flavors being identified by the Aim 1 panel which reflected the findings in the study done by Lorén et al, 2023. The Aim 1 panel response was clear that sodium needed to be added back in but modified to ensure that the 40% level was reached.

Hummus was described as an emulsified encapsulated microstructure containing chickpea paste, tahini, and lemon juice (Ahmed et al, 2020). In deciding which brand of chickpea to use, a key factor was the presence of various preservatives and what type of sodium was present. Rinsing and letting the chickpeas rest for two minutes post as part of the process in both Aim 1 and Aim 2 reduced the sodium by 40%, confirming the findings by Duyff et all in 2011. The brand used in the study had whole chickpeas that remained intact post rinsing. It was decided to not use dried chickpeas to reduce the potential for microbial outgrowth noted in the studies by Ahmed et all in 2020 and Salazar et al in 2022.

Evora™ S40 as an ingredient was very easy to work with. Previous work with sugar substitutes such as Stevia ™ were used as examples for the panels when talking about usage rates. The amount needing to be added is significantly less yet gives the same flavor as if the standard ingredient was used. This was the case for this ingredient as it was added as a percentage to the overall formulation.

Adding Evora™ S40 to lemon juice in Aim 1 led to comments about astringency and amplified the roasted flavor of the tahini or the citrus note of the lemon juice. Adding the treatment to water in Aim 2 gave a more well-rounded taste as well as improved mixing with other ingredients. Aim 3 consumer sensory panels found the garlic and lemon aftertaste to be refreshing and cleansing. Panelists also commented that the lemon note was refreshing at the end and not typically noticed with commercial hummus. Some of the panelists inquired if it was available for purchase in the store.

Use of a free online nutritional calculator from FSANZ (Food Standards Australia New Zealand) allowed for the total sodium levels to be calculated in a nutritional information panel (NIP) to ensure that the 40% reduction was achieved in Aim 1 and maintained in Aim 2. FSANZ software was recommended to the researcher as a cost-effective tool.

Even with the reduction, the JAR saltiness question that was asked to both panels showed that all the samples were not salty enough. Saltiness is more subjective than originally thought. Just about right as a question should have scored 80%, with outlying not salty enough or too salty getting the other 20%. Further research in how to best show 40% reduction to the consumer is needed as perception of sodium is varied. A study on how salty does one like their food could identify various aspects and provide a clearer picture. Treatment cannot make up for the lack of salt taste picked up by the panels.

None of the panelists were asked their age or gender identification as dietary preferences was the focus. As a general statement, the average age of the participants was 30-50 years old, mainly female. Texture and taste were key attributes to this study, which confirmed the research done by Ahmed et al, 2022. Also confirmed was that taste perception is subjective to the individual. As one grows older, the ability to perceive salt and sweet diminishes. This is due to the amount of taste buds shrinking and functioning as well as in ones younger years. This was seen with the data from consumer panels. Most panelists were onmitarians who ate plant-based foods at least weekly. This mirrored the Wallace at al, 2016 findings on hummus consumers tending to eat more vegetables and fruits when compared to non-consumers. Further research should include age and perception of sodium, as they would give further insight on food and taste perception.

One hundred persons were actively sought to participate in the panels through posters, email, social media, and word of mouth. Seventy persons signed up and only two did not show for the panels. Long term loss of taste and smell along with sensitivity to garlic were noted reasons on why some of the student body didn't participate. Final participant count was sixty-seven due to one panelist being disqualified due to having a cold with limited taste and smell. Six of the food industry panelists from Aim 1 participated in in the Aim 3 panel. Only one of the original panelists was not able to participate in the Aim 3 panel. All but one participant chose Evora™ S40 C 0.75% as their most liked overall. One person chose the high salt. None of the original participants were aware of selections made until after the panel was over. It was interesting to note that the overall flavor of the sample was the deciding factor.

Overall comments about the panel and hummus were positive. The level of garlic and lemon in the samples was one topic that gained the most feedback. Some felt that the samples needed more garlic and salt, whereas others felt that these flavors overpowered the hummus. When asked about the garlic type, a few panelists were surprised that the garlic was powder. Similar feedback was given about the amount of lemon and overall flavor. A few panelists commented that the garlic note at first with the lemon finished made their mouth feel refreshed. Some felt that there was too much garlic or lemon. None of the panel members mentioned astringency or bitter notes in their comments.

The panelists had a tough time choosing between the High Salt B 0% and Evora™ S40 C at 0.75% as the overall preferred sample from the three options. Statistics states that there was no one sample was liked more than the others. Lack of difference in the overall ranking showed no difference among the samples. Some felt that the aftertaste of Evora™ S40 F at 1.50% was too strong. Panelists who got the High

Salt B 0% or Evora™ S40 C 0.75% first typically chose that sample as their most preferred. Even though the overall ranking of the samples was found to not be significant, the feedback from the panel was considered important and relevant.

Chapter 6: Conclusion

The FDA published a guidance document in October 2021 that outlined the agencies plans to reduce the levels of sodium in the typical American diet. As part of the guidance outcomes, the FDA identified a short-term goal of 12% sodium reduction over the next 2.5 years and a long-term goal of 40% over the next decade (FDA, 2021). This study showed that reducing the sodium level in hummus by 40% along with using a naturally derived sodium reducer was achievable and found to be acceptable to the general consumer.

The purpose of this study was to determine consumer acceptance of a naturally derived sodium reducing ingredient when used in a known product in the marketplace (chickpea hummus). By reducing the sodium level by 40% using naturally derived sodium reducing ingredients, food manufacturers will have healthier alternatives than commonly used traditional sodium agents. The null hypothesis was rejected and the alternate hypothesis was accepted as the samples differed in both sodium content and acceptability.

This study had three specific aims. Aim 1 was to create a recipe for chickpea hummus that reduced the sodium content by 40% using a naturally derived ingredient (Evora™ S40) that were acceptable to seven food industry peers. Aim 2 was based on Aim 1 findings, test versions for salt level, texture, pH, water activity, spoilage and microbial pathogens (*Salmonella*, *Listeria*, *Lactic Acid*, and *Coliform/ E. coli)* to verify that items were safe for human consumption. Aim 3 determined overall consumer perception of sodium by using the control (traditional hummus) and two Evora™ S40 versions from Aim 1. The overall hummus chosen by the consumer panel was a draw between the high salt 0% and the Evora™ S40 C at 0.75%. This shows that the consumer could not differentiate between the treatment and the control.

All three Aims were met with favorable results even with most findings not being statistically significant. The only statistically significant aspect observed was aftertaste in Aim 3. The overall panel feedback on the hummus was positive.

The limitations of this study did not deter the study from concluding. Though the aims were met, knowledge was gained in how to problem solve when aspects of the aims were moving away from resolution. Limitation to Aim 1 was the number of panelists, as the small sample size N=7 decreased the ability to detect statistical significance of the panel findings. Yet having a small panel in Aim 1 was very insightful as it led to formulation improvements that were well received in Aim 3. The research into solutions along with the ability to ask the questions was as valuable as the study itself.

This study was designed to be easily repeatable as changes to treatments along with ease of completing recipe was incorporated into the design. Aspects of treatments along with microbial testing will lead to further and future learning. Future research using different equipment such as a food processor or hand blender and compare see if texture and overall appearance could be improved. Pulsing versus speed mixing may give insight to texture development. Incorporating the use of other treatments to reduce pathogenic outgrowth such as roasting the chickpeas or using high pressure pasteurization (HPP) might lead to flavor enhancements. Other treatments could include the use of herbs and spices to improve flavor.

Further research in how to best show 40% reduction to the consumer is needed as perception of sodium is varied. A study on how salty does one like their food could identify various aspects and provide a clearer picture. Treatment cannot make up for the lack of salt taste picked up by the panels. Further research should also include age and perception of sodium, as they would give further insight on food and taste perception.

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Appendix A

Table 1. from Wallace et al 2016:

Table 1. Nutritional profile of chickpeas and hummus.

Nutrient	Unit	DV [b]	Value per 100 g [a]		
			Chickpeas, Dry (16056) [c]	Chickpeas, Cooked (16057) [c]	Hummus (16158) [c]
Macronutrients					
Energy	Kcal	2000	378	164	166
Protein	g	50	20.47	8.86	7.90
Fat	g	78	6.04	2.59	9.60
Carbohydrate	g	275	62.95	27.42	14.29
Fiber	g	28	12.2	7.6	6.0
Sugar	g		10.7	4.8	NR
Minerals					
Calcium	mg	1300	57	49	38
Iron	mg	18	4.31	2.89	2.44
Magnesium	mg	400	79	48	71
Phosphorus	mg	1000	252	168	176
Potassium	mg	4700	718	291	228
Sodium	mg	2300	24	7	379
Zinc	mg	15	2.76	1.53	1.83
Copper	mg	2	0.656	0.352	0.527
Manganese	mg	2	21.306	1.030	0.773
Selenium	μg	70	0	3.7	2.6
Vitamins					
Vitamin C	mg	60	4.0	1.3	0
Thiamin	mg	1.5	0.477	0.116	0.180
Riboflavin	mg	1.7	0.212	0.063	0.064
Niacin	mg	20	1.541	0.526	0.582
Pantothenic acid	mg	10	1.588	0.286	0.132
Vitamin B6	mg	2	0.535	0.139	0.200
Folate	μg	400	557	172	83
Choline	mg	550	99.3	42.8	NR
Vitamin B12	μg	6	0	0	0
Vitamin A	IU	5000	67	27	30
Vitamin D	μg	20	0	0	0
Vitamin K	μg	80	9.0	4.0	NR
Vitamin E	mg	30	0.82	0.35	NR
Lipids					
Saturated	g	20	0.603	0.269	1.437
Monounsaturated	g	ND	1.377	0.583	4.039
Polyunsaturated	g	ND	2.731	1.156	3.613

[a] Data obtained from the USDA National Nutrient Database for Standard Reference; [b] Based on a caloric intake of 2000 kcal, for adults and children four of more years of age; [c] Nutrient Database Number (NDB No.) in the USDA Food Composition Databases. (https://ndb.nal.usda.gov/ndb/). DV = daily value; NR = not reported; ND = no data.

Table 2. Aim 1 Recipes

	Control A	%	High Salt B	%	S40 C @ 0.75%	%
Chickpeas	10.000	55.59	10.000	55.49	10.000	55.20
Lemon	2.700	15.01	2.700	14.98	2.700	14.90
Tahini	2.500	13.90	2.500	13.87	2.500	13.80
Garlic	0.080	0.44	0.080	0.44	0.080	0.44
Water	2.700	15.01	2.700	14.98	2.700	14.90
Salt	0.010	0.06	0.040	0.22	0.000	0.00
Evora™ S40	0.000	0.00	0.000	0.00	0.135	0.75
Total ounces	17.990	100	18.020	100	18.115	100.00

	S40 D @ 1%	%	S40 E @ 1.25%	%	S40 F @ 1.50%	%
Chickpeas	10.000	55.06	10.000	54.92	10.000	54.78
Lemon	2.700	14.87	2.700	14.83	2.700	14.79
Tahini	2.500	13.77	2.500	13.73	2.500	13.70
Garlic	0.080	0.44	0.080	0.44	0.080	0.44
Water	2.700	14.87	2.700	14.83	2.700	14.79
Salt	0.000	0.00	0.000	0.00	0.000	0.00
S40	0.182	1.00	0.228	1.25	0.274	1.50
Total ounces	18.162	100.00	18.208	100.00	18.254	100.00

Table 3. Aim 3 Recipes

	High Salt B 0%	%	**S40 C @ 0.75%**	%	**S40 F @ 1.5%**	%
Chickpeas	70.000	55.49	70.000	55.06	70.000	54.78
Lemon	18.900	14.98	18.900	14.87	18.900	14.79
Tahini	17.500	13.87	17.500	13.77	17.500	13.70
Garlic	0.560	0.44	0.560	0.44	0.560	0.44
Water	18.900	14.98	18.900	14.87	18.900	14.79
Salt	0.280	0.22	0.161	0.13	0.161	0.13
Evora™ S40	**0.00**	**0.00**	0.950	**0.75**	1.920	**1.50**
Total ounces	126.140	100	127.130	100.00	127.780	100.00

Table 4. Food Safety Parameters

Analytical Test	Specification
pH	<5
Aw	<0.980
CFT	Meets
Sodium Calculation (NIP)	Control: 288mg Both S40: 173 mg
Moisture	60-65
Texture	Per machine reading

All methods are AOAC.

Table 5: Microbial Test listing AOAC or FDA BAM Method and specification

Microbial Test	**AOAC or FDA BAM Method**	**Specification**
3M Petrifilm *Coliform/E. coli*	AOAC 991.14	<100 cfu/g for both
3M Petrifilm Lactic acid	AOAC Certificate # 041701	<10000 cfu/ gram
3M Petrifilm *Salmonella spp.* SALX with supplement	AOAC 2014.01	Negative
Listeria spp. Oxford media with supplement	FDA BAM M103	Negative
Listeria spp. on Bio-Rad RAPID'*L.Mono*	AOAC Certificate# 030406	Negative
3M Petrifilm Environmental *Listeria*	AOAC Certificate # 030601	Negative

Appendix B

Table 6. Pre-tasting Demographic Questions

1 **The hummus samples contain the following ingredients: chickpeas, garlic, lemon, salt, and sesame (as tahini paste).**

Are you allergic or have a sensitivity to any of the above listed ingredients?

Yes ○ No ○

2 **Have you lost your sense of taste or smell due to illness?**

Yes ○ No ○

3 **Have you smoked within the past hour?**

Yes ○ No ○

Note. Answering yes to any of the above questions triggers the panelist to alert the test administrator that they are eliminated from the panel.

NOTE: Only answer this question if on question #1 of questionnaire page 1 your answer was one of the following: "Yes"

You are not eligible to participate. End of test - please see administrator.

4 **Has your sense of taste or smell changed or altered due to pregnancy?**

Background: This panel deals specifically with the perception of sodium and taste plays a key part. During pregnancy, the sense of smell and taste sometimes is heightened. Other times, taste and smell may lead a favorite food or beverage to not be tolerated such as coffee or chicken.

Yes ○ No ○ Not Applicable ○

5 What is your dietary or food preference? Select the option that best fits your food preference.

Definitions:

- **Omnitarian: Eats everything (vegetables, meat, fish, etc).**
- **Carnivore: Eats only meat, no fruits or vegetables.**
- **Flexitarian: Eats vegetables, plant based foods, and the occasional meat, fish, and poultry**
- **Pescatarian: Eats vegetables, fish, and seafood. No meat or poultry**
- **Vegetarian: Eats vegetables and plant based foods.**
- **Vegan: Eats only vegetables and plant based foods. Does not eat or use any animal products or byproducts.**

Omnitarian	Carnivore	Flexitarian	Pescatarian	Vegetarian	Vegan
○	○	○	○	○	○

6 How often do you consume or purchase plant based foods?

Daily	Weekly	Every other week	Monthly	Have never purchased or consumed
○	○	○	○	○

Table 7. Questions asked with each sample tasted **(Aim 1 has 6 samples and Aim 3 has 3 samples).**

1 **Please answer the following questions regarding each of the following attributes for the sample that you just tasted.**

	Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
Aroma	○	○	○	○	○	○	○	○	○
Appearance	○	○	○	○	○	○	○	○	○
Texture	○	○	○	○	○	○	○	○	○
Overall Flavor	○	○	○	○	○	○	○	○	○
Garlic Flavor	○	○	○	○	○	○	○	○	○
Lemon Flavor	○	○	○	○	○	○	○	○	○
Aftertaste	○	○	○	○	○	○	○	○	○

2 **Saltiness**

Not At All Salty Enough	Not Quite Salty Enough	Just About Right	Slightly Too Salty	Much Too Salty
○	○	○	○	○

3 **Please select the phrase that best describes your overall opinion of this product.**

OVERALL OPINION

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like Nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
○	○	○	○	○	○	○	○	○

4 What did you like about this sample? (*Please be as specific as possible*)

5 What did you dislike about this sample? (*Please be as specific as possible*)

Table 8. Aim 1 specific questions regarding overall preference per set of samples

After Control A and High Salt Control B

Which of the following products do you prefer?

276	189	No Preference
○	○	○

After S40 C and S40 D

Which of the following products do you prefer?

354	432	No Preference
○	○	○

After S40 E and S40 F

Which of the following products do you prefer?

690	510	No Preference
○	○	○

Table 9. Aim 3 specific questions regarding overall preference

This consumer study looked at the perception of sodium in chickpea hummus and the use of plant based ingredients to replace the sodium by 40%.

After tasting the samples, how likely would you be to purchase a product that contains a plant based ingredient that reduces the sodium?

Much More Likely	More Likely	About the same	Less Likely	Much Less likely
○	○	○	○	○

Please rank the products listed below, in the order that you prefer them from most to least.

Start by clicking the product code which you like MOST, followed by clicking the product code which you like SECOND, continuing until the final product code you click is the one you like LEAST.

After you make your selections the product codes will appear in the space below with the product you liked MOST on the left to the product you liked LEAST on right.

If you'd like to change the order of your responses, click the "Reset" button in the lower right-hand corner.

147 258 369

reset

Why did you rank these items this way?

Appendix C

Table 10. Aim 1 Results

A. Food Safety Parameter results.

All methods are AOAC.	Samples and Evora™ S40 treatment levels (percentage)					
	Control A @ 0%	**High Salt B @ 0%**	**S40 C @ 0.75%**	**S40 D @ 1.00%**	**S40 E @ 1.25%**	**S40 F @ 1.50%**
Test						
pH	4.45	4.47	4.61	4.58	4.61	4.92
Aw	0.992	0.986	0.993	0.989	0.990	0.992
Sodium NIP	153mg rinsed*	296 mg unrinsed	133 mg rinsed*	133 mg rinsed*	133 mg rinsed*	133 mg rinsed*
Moisture	66.94	69.37	65.54	67.46	67.69	66.94
CFT	Meets	Meets	Meets	Meets	Meets, thinner	Meets
Color	L: 51.6 a: 4.6 b: 17.5	L: 60.8 a: 5.8 b: 21.7	L: 60.9 a: 5.5 b: 20.6	L: 55.9 a: 5.2 b: 19.6	L: 55.2 a: 5.1 b: 18.9	L: 53.8 a: 5.3 b: 19.1

*Rinsed with water and allowed to rest for 2 min to remove 40% sodium

B. Sodium NIP Panels

NUTRITION INFORMATION

Servings per package: 18

Serving size: 28.45 g

	Average Quantity per Serving	Average Quantity per 100 g
Energy	186 kJ	655 kJ
Protein	1.8 g	6.4 g
Fat, total	2.7 g	9.6 g
- saturated	0.3 g	1 g
Carbohydrate	3.5 g	12.2 g
- sugars	0.4 g	1.5 g
Sodium	44 mg	153 mg

NUTRITION INFORMATION

Servings per package: 18

Serving size: 28.45 g

	Average Quantity per Serving	Average Quantity per 100 g
Energy	186 kJ	654 kJ
Protein	1.8 g	6.3 g
Fat, total	2.7 g	9.6 g
- saturated	0.3 g	1 g
Carbohydrate	3.5 g	12.2 g
- sugars	0.4 g	1.4 g
Sodium	84 mg	296 mg

NUTRITION INFORMATION

Servings per package: 18

Serving size: 28.45 g

	Average Quantity per Serving	Average Quantity per 100 g
Energy	188 kJ	661 kJ
Protein	1.9 g	6.6 g
Fat, total	2.7 g	9.5 g
- saturated	0.3 g	1 g
Carbohydrate	3.6 g	12.5 g
- sugars	0.4 g	1.5 g
Sodium	38 mg	133 mg

NIP Panels left to right: Control A, High Salt B, Evora™ S40 samples (C, D, E, and F).

Table 11. Aim 1 Food Industry Panel Results

A. Question relating to frequency of consuming or purchase

How often do you consume or purchase plant-based foods?	
Count n=7	
Have never purchased or consumed	0%
Monthly	43%
Every other week	14%
Weekly	14%
Daily	29%

B. Likert Scale: 1-9 (1=dislike extremely to 9=like extremely) and Just About Right (JAR) Saltiness

	Samples and Evora™ S40 treatment levels					
Count n=7	**Control A @ 0%**	**High Salt B @ 0%**	**S40 C @ 0.75%**	**S40 D @ 1.00%**	**S40 E @ 1.25%**	**S40 F @ 1.50%**
Liking Grid: Aroma	5.86A	6.86A	6.00A	7.00A	5.86A	5.43A
Liking Grid: Appearance	6.43AB	6.71A	6.71A	6.57A	6.00AB	5.29B
Liking Grid: Texture	6.43A	6.71A	6.57A	6.14A	6.00A	5.86A
Liking Grid: Overall Flavor	4.86B	7.14A	5.57AB	6.43AB	5.43AB	5.14B
Liking Grid: Garlic Flavor	5.00A	5.86A	5.14A	5.86A	4.86A	4.57A
Liking Grid: Lemon Flavor	4.71A	5.86A	5.00A	5.71A	4.57A	4.14A
Liking Grid: Aftertaste	4.86A	5.29A	4.71A	5.57A	4.43A	4.14A
Overall Opinion	5.29A	6.57A	5.43A	6.29A	4.71A	5.29A

Just About Right (JAR) Saltiness

	Samples and Evora™ S40 treatment levels					
	Control A @ 0%	**High Salt B @ 0%**	**S40 C @ 0.75%**	**S40 D @ 1.00%**	**S40 E @ 1.25%**	**S40 F @ 1.50%**
Count	**7**	**7**	**7**	**7**	**7**	**7**
Much Too Salty	0%	0%	0%	0%	0%	0%
Slightly Too Salty	14%	0%	0%	0%	14%	29%
Just About Right	29%	57%	43%	57%	29%	43%
Not Quite Salty Enough	14%	29%	43%	29%	43%	14%
Not At All Salty Enough	43%	14%	14%	14%	14%	14%

Figure 1. Aim 1 Preference

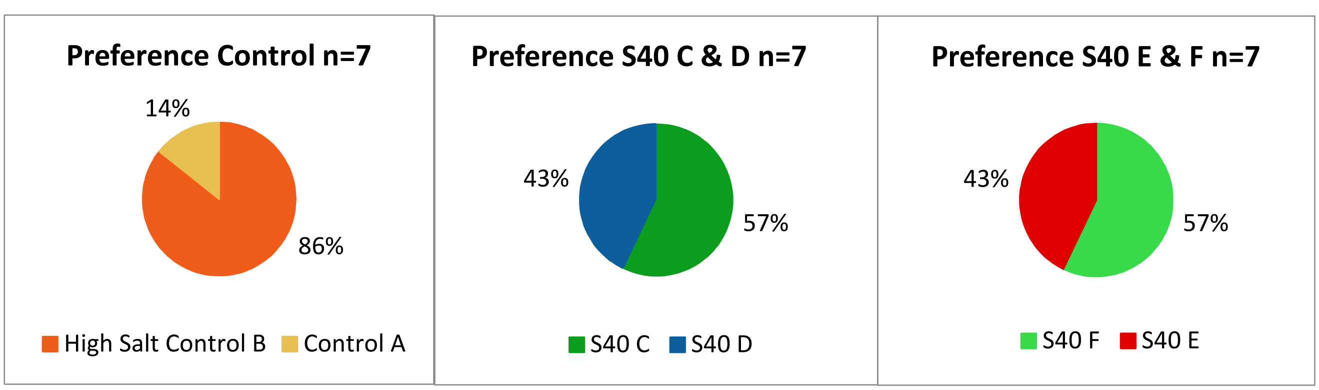


Table 12. Aim 2 results

A. Food Safety Parameter results.

Test	Samples and Evora™ S40 treatment levels (percentage) High Salt B @ 0%	S40 C @ 0.75%	S40 F @ 1.50%
pH	3.73	3.89	4.07
Aw	0.9903	0.9916	0.9935
Sodium Calc *NIP	288 mg unrinsed	173 mg rinsed*	173 mg rinsed*
Moisture	65.92	66.04	64.47
CFT	meets	meets	meets
Color	L: 61.4 a: 6.3 b: 21.1	L: 40.4 a: 4.4 b: 15.9	L: 47.7 a: 3.9 b: 19.0

B. Sodium NIP Panels

NUTRITION INFORMATION
Servings per package: 18
Serving size: 28.34 g

	Average Quantity per Serving	Average Quantity per 100 g
Energy	128 kJ	452 kJ
Protein	1.3 g	4.5 g
Fat, total	1.1 g	3.8 g
- saturated	0.1 g	0.4 g
Carbohydrate	3.7 g	12.9 g
- sugars	0.4 g	1.4 g
Sodium	82 mg	288 mg

NUTRITION INFORMATION
Servings per package: 18
Serving size: 28.34 g

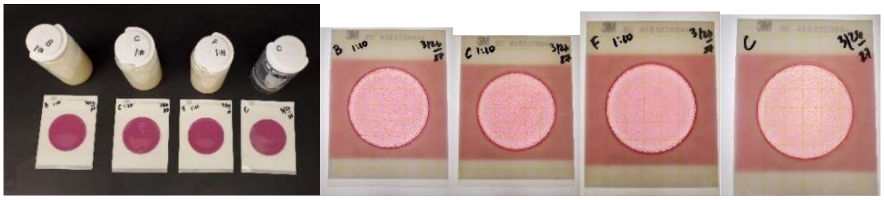
	Average Quantity per Serving	Average Quantity per 100 g
Energy	118 kJ	415 kJ
Protein	1.4 g	4.8 g
Fat, total	1.1 g	3.8 g
- saturated	0.1 g	0.4 g
Carbohydrate	3.7 g	13.2 g
- sugars	0.4 g	1.4 g
Sodium	49 mg	173 mg

NIP Panels left to right: HS Control B and Evora™ *S40 samples (C: 0.75% and F:1.5%).*

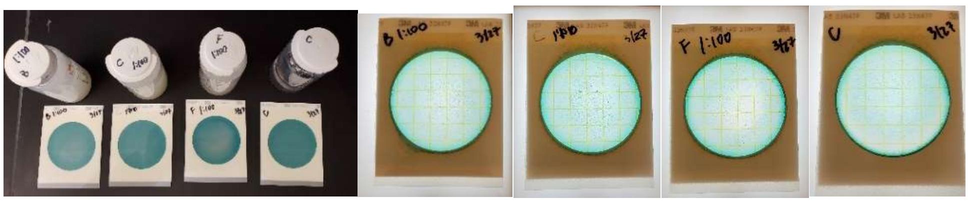
Table 13. Aim 2 Microbial spoilage and pathogen results

			Samples and Evora™ S40 treatment levels (percentage)		
			High Salt B @ 0%	S40 C @ 0.75%	S40 F @ 1.50%
Test	**Amount/Rate**	**Specification**			
3M Petrifilm Coliform/ E.coli	1:10 dilution	<100	C: <10 cfu/g E: <10 cfu/g	C: <10 cfu/g E: <10 cfu/g	C: <10 cfu/g E: <10 cfu/g
3M Petrifilm Lactic Acid Bacteria	1:100 dilution	<10000	1000 cfu/g	1100 cfu/g	1300 cfu/g
3M Petrifilm Salmonella SALX (media with suppliment)	25g in 225mL (Streak plate from enrichment)	Negative for *Salmonella* spp.	Negative	Negative	Negative
BioRad RapidL'mono Plates	25g in 225mL (Streak plate from enrichment)	Negative for *Listeria* spp.	Negative: No growth on plates.	Negative: No growth on plates.	Negative: No growth on plates.
Listeria (Oxford media with suppliment)	25g in 225mL (Streak plate from enrichment)	Negative for *Listeria monocytogenes*	Negative	Negative	Negative
3M Petrifilm Environmental Listeria	25g in 225mL	Negative for *Listeria* spp.	Negative	Negative	Negative

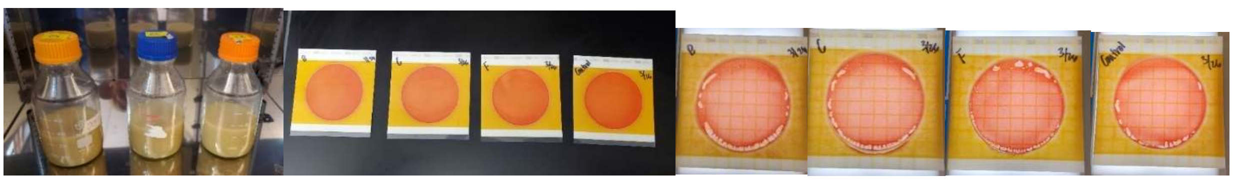
Figure 2. Aim 2 Pictures of micro plates: Pre and post plating.



3M Coliform and E. Coli plates

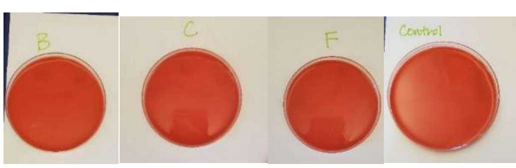


3M Lactic acid bacteria plates

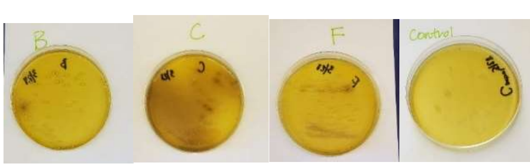


3M SALX system: Picture 1 is SALX enrichment. Picture 2 are hydrated plates. Pictures in last row are completed plates with no counts.

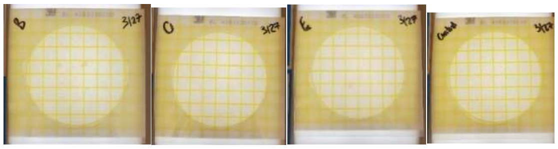
Listeria testing: Picture 1 is Listeria enrichment. Plates Top row is BioRad RapidL'mono. Middle Row is Oxford media with supploement. Last row is 3M Environmental Listeria.



*RapidL'mono plates: Negative for Listeria. N**o growth observed.** Plated from Listeria Enrichment*



Listeria Oxford Media: Negative for Listeria as observed darkening is light brown.



3M Environmental Listeria: Negative for Listeria from Listeria Enrichment.

Figure 3. Aim 3 Pictures of sensory testing

From left to right, samples labeled in one ounce cups, participant view, and researcher view

Table 14. Aim 3 Consumer Panel Results

A. Question relating to frequency of consuming or purchase

How often do you consume or purchase plant-based foods? Count n = 67	
Have never purchased or consumed	7%
Monthly	21%
Every other week	7%
Weekly	31%
Daily	33%

B. Likert Scale: 1-9 (1=dislike extremely to 9=like extremely) and Just About Right (JAR) Saltiness

	Treatment level of Evora ™ S40		
Count n = 67	**High Salt 0%**	**0.75%**	**1.50%**
Liking Grid: Aroma	6.61A	6.40A	6.55A
Liking Grid: Appearance	7.00A	6.90A	6.72A
Liking Grid: Texture	6.93A	6.97A	6.39A
Liking Grid: Overall Flavor	6.57A	6.69A	6.21A
Liking Grid: Garlic Flavor	6.24A	6.37A	5.93A
Liking Grid: Lemon Flavor	5.87A	6.34A	5.76A
Liking Grid: Aftertaste*	**6.27AB**	**6.30A**	**5.55B**
Overall Opinion	6.51A	6.49A	6.07A

**Statistically significant with a p-value of 0.025 and confidence of 97.5%*

Just About Right (JAR) Saltiness

	Treatment level of Evora ™ S40		
	High Salt 0%	**0.75%**	**1.50%**
Count	**67**	**67**	**67**
Much Too Salty	1%	0%	3%
Slightly Too Salty	7%	10%	16%
Just About Right	66%	52%	54%
Not Quite Salty Enough	22%	36%	25%
Not At All Salty Enough	3%	1%	1%

Table 15. Aim 3 Consumer Panel Sample Ranking

A. Question on likelihood of purchasing a product post panel

Ranking: Data	**Count n = 67**
After tasting the samples, how likely would you be to purchase a product that contains a plant-based ingredient that reduces the sodium?	
Much More Likely	**21%**
More Likely	**54%**
About the same	**19%**
Less Likely	**4%**
Much Less likely	**1%**

B. Ranking of three samples by consumer panel with equation

Ranking: Ranking

P-Value:	0.137
Confidence:	86%
Stat Method:	Friedman's Two-way
Significant:	**FALSE**

Samples ranked most (1) to least (3)

	Treatment level of Evora ™ S40		
	High Salt 0%	**0.75%**	**1.50%**
Count (N=)	67	67	67
Rank 1	36%	37%	27%
Rank 2	34%	39%	27%
Rank 3	30%	24%	46%
Rank Sum	**130**	**125**	**147**
Post Hoc			

Equation $$Q = \frac{12}{nk(k+1)}\sum_{j=1}^{k} R_j^2 - 3n(k+1)$$

n=67

k=3

Rj = rank sum

Rj² = sum of squared rank sums

Q=Friedmans 2-way rank sum

Figure 4. Word cloud from consumer panel final ranking

Word cloud from ranking data: Top 10 words listed from question "Why did you rank the items this way?"