GLASS CLOSURE EVALUATION: FACTORS AFFECTING VACUUM IN MODEL FOODS AND CLOSURE INTEGRITY OF EEASY LIDS

A Project Paper

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Natasha Saikia

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ABSTRACT

Food preservation is a practice that has been believed to have aroused along with agriculture to sustain food supplies in periods of scarcity. Food packaging along with the basic function of containing the food has a major role in protecting the food against physical damage, microorganisms, tampering, and physiochemical degradation. It also helps to maintain product nutrition, safety, and shelf life. This project is focused on the factors that influence the integrity of a hermetic seal for glass containers with metal lids used for shelf-stable foods.

The effects of water activity, hot-pack temperature, and headspace on the vacuum measurements in glass closures were evaluated. Tests were performed in triplicates with glucose solutions as model foods ranging in water activity from 0.6 to 1, hot-pack temperature from 170°F to 200 °F and headspace of 6% and 10%. Results indicated that vacuum levels decreased with lower hot-pack temperatures, reduced water activity values, and increased headspace volume. There was at least a 1.5-fold increase in vacuum levels after steam flushing the headspace in the jars compared to just hot packing.

The evaluation of closure integrity of tomato sauce jars when using the new EEasy Lids was tested by measuring vacuum, removal torque, security and pull-up values. EEasy Lids is a major innovation in the lid industry which reduces the torque needed to open the glass jar significantly. Compared with standard lug lids presently in the market, the EEasy lids needed a removal torque in the range of 11.5-15 lb-in compared to 20-28 lb-in for standard lids.

BIOGRAPHICAL SKETCH

Natasha Saikia is a student pursuing a Master of Food Science degree with a focus on Food Safety and Quality Assurance. Prior to attending Cornell University, she completed her undergraduate degree in Bachelor of Technology in Biotechnology from Vellore Institute of Technology, India in 2020. She believes that Food Safety is the foundation of the food industry and working towards a safe and sustainable food industry is an important and rewarding responsibility.

Her love for food and culinary comes from her mother who is the happiest when she is in her garden and proudest when she can serve dishes from her garden to the family. After the completion of her MFS degree Natasha hopes to work for a company where she can combine her love for food and passion for technology, contributing to a more sustainable food system.

Dedicated to:

My mother, Manashi Saikia for supporting and trusting my dreams

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I would like to thank everyone who supported my academic journey at Cornell University. Thank You to Dr Olga Padilla- Zakour for giving me the opportunity to work on this project, mentoring and guiding me to execute this project successfully. Shuang Qiu for assisting me with lab work. Brandon Bach, James Bach, John Ryder and Jim Heaton of CCT lids who played a major role in my project and provided funding to complete the tests. Thank you to the staff at Cornell Agritech for helping me perform the experiments. Finally thank you to my friends and family for their much-needed support and encouragement.

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CHAPTER 1

Introduction

Food, usually of plant or animal origin containing essential nutrients: carbohydrates, proteins, fats, vitamins and minerals, is needed by the body to support growth, provide energy and sustain life. Food spoilage can be caused due to microbial, chemical and physical factors (3). Unsafe food can cause illness and in some cases is life threatening to consumers and therefore, ensuring food safety conditions or practices to maintain the integrity of food is crucial (24). Food preservation has been a practice even before recorded history. Historians believe food preservation arose along with agriculture due to the need to sustain food supplies during potential hunger periods such as droughts and cold winters (23). Ancient ambitious research and serendipity led to the discovery of techniques of preserving food such as freezing, drying, cooling, salting, pickling and smoking which are still practiced today with the help of modern technology (18).

Factors Affecting Preservation of Food

Acidity and water content of the food are the two most important factors influencing the preservation of food (26). Water content includes moisture content but more importantly the water activity of the food. According to the FDA, water activity is defined as “the ratio between the vapor pressure of the food itself, when in a completely undisturbed balance with the surrounding air media, and the vapor pressure of distilled water under identical conditions” (28). In simple words, water activity is the available water that microorganisms may use to facilitate their growth or diffuse throughout the food. All foods have a water activity in the range of 0 to 1 a_w. a_w of 0 is when the food is bone dry which is rarely seen. Most foods are within the range of 0.2 to 0.9. The water activity can provide important information regarding the safety as well as the quality of the food. Each microorganism has a specific tolerance level for water activity, below which they will not be able to grow. At an a_w value lower than 0.6 no microorganism can survive therefore common foods such dried pasta, dried spices, crackers and honey are shelf stable at room temperature (28). Foods with water activity below 0.85 do not support the growth of harmful microorganisms therefore are generally considered safe and non-toxic (28). Acids in foods, which are either added or naturally present have a large impact on the type of microorganism that can grow on them. Acids can inhibit, slow down the growth and destroy microorganisms. According to the acidity of foods, we can divide them into acid, low acid and acidified foods (4). A pH value of 4.6 is the dividing line for acid and low acid foods as *Clostridium botulinum,* a deadly toxin producing microorganism, grows at a pH above 4.6 and a_w of 0.93 or higher in anaerobic conditions. Several foods have a pH low enough to offer some degree of protection; however, very few foods have a pH low enough to completely check the growth of microorganisms (4). For this reason, almost all foods have additional microbial controls applied to preserve foods, such as refrigeration, heating, freezing or drying. The most common amongst these is canning in a hermetically sealed container. Time and temperature are the most important pieces of information in the canning operation. The time in this case does not refer to the time required to cook the food, but the heating time needed for the product to reach "commercial sterility". Commercial sterility is defined as the state where harmful microorganisms and those capable of causing food spoilage, have been killed (10). The factors influencing this temperature time regime are pH, a_w, viscosity and particle size of the food, dimensions of the container and temperature of the cooking medium. For canning, pH and a_w are the most important factors due to *Clostridium botulinum,* which produces a dormant spore (15).

This spore is difficult to kill and can remain dormant for many years. Improperly processed cans therefore create an ideal environment for these opportunistic bacteria to grow and produce one of the deadliest neurotoxins to humankind. For low acid foods, heating at high temperatures for a long period of time is the kill step for these spores. For foods with water activities in the range of 0.60 and 0.85, that do not present a *C. botulinum* risk, preservatives can be added to to an extent where they can kill the vegetative cells of spoilage microorganisms or prevent the growth of mold in foods (4). They work by inhibiting enzymes, denaturing proteins, or destroying and altering the cell walls of the microorganisms (14). Some examples of preservatives are calcium propionate in breads to inhibit mold, sodium benzoate in hummus to inhibit yeast and mold, and natamycin added to cheese to inhibit fungi (12,14).

Glass Containers in Food Packaging

Glass containers have a long history in food packaging with the first recorded incidence around 3000 BC. Its production involves the heating of materials like limestone, sodium carbonate, and former glass at high temperatures for them to melt into a thick mass which can be poured into molds to form the desired shape and size (5). The glass container has three basic parts namely finish, body and the bottom (7, 19). The top part of the glass container which consists of the opening is the finish. The three general finishes are lug lids, press-on/twist off and continuous thread lids. The Glass Packaging Institute has set standardized dimensions and specifications for each type of closure (5). Ensuring a tamper proof seal is crucial to maintain the organoleptic properties of the food and extending its shelf life. Vacuum inside the glass jar and the resultant positive pressure are important considerations in the packaging industry. A raised circular area in the center of the lid called the safety button helps to detect low or no vacuum packages in automatic operations and serves as a visual indicator to the consumers (1). The factors affecting vacuum formation are headspace, product sealing temperature, air in the product and capper vacuum efficiency (5). Sufficient headspace is particularly important for low acid foods to ensure a good seal and allow for product expansion during retorting. The required headspace differs with the type of product, but a general rule of thumb is in the range of six percent to ten percent of the container volume (5). Keeping all the other factors constant, the higher the product temperature at the time of sealing, the more the vacuum after cooling. The air in the product should be kept at a minimum to ensure a good seal, product appearance and product quality.

Lids Used in Glass Containers

Lug lids are widely used in the food industry due to the high application speeds achieved as it is a partial turn closure, and the ease in opening and resealing by the consumer. The lids have a metal shell with a straight or fluted skirt (5). Depending on the type of lid there can be between three to eight lugs and a diameter ranging from 27 to 110 millimeters (29). The lids are lined with plastisol to provide a tamper-proof hermetic seal. The lids need to be inspected by trained professionals at regular intervals to ensure the integrity of the seals. There are two types of inspections depending on whether the cap needs to be removed or not. Visual examinations are non-destructive and are performed at frequent intervals (5). Pull up is a type of visual check to measure the fit of the closure lugs on the lugs of the glass jar. It is defined as the "distance between the leading edge of the cap lug and the vertical neck ring seam on the glass finish" (5). Federal regulations require physical examinations for defects to be performed by trained individuals at sufficient frequency to ensure proper closure. It includes vacuum check, temperature measurement, headspace, gasket impression, removal torque, pull up and security. Removal torque is the amount of force needed to remove the cap measured using a torque meter. Security, defined as the lug tension of an applied closure, is the most dependable measurement to ensure a good seal (29). If the value is higher than the range specified by the manufacturer it indicates over-application and vice versa.

Tomato Sauce Manufacturing

The tomato sauce making process is fairly simple and generally involves the following steps - pulping, adding ingredients and cooking, finishing, removing air, filling, cooling and labelling (13). During pulping the tomatoes are sliced and precooked and then pumped into cyclones or pumping machines which separate the skins, seeds and stems from the pulp. The pulp is then processed further and pumped into kettles where it is cooked (11). After heating the sample at a temperature above 80 degrees Celsius, ingredients such as salt, sweetener, vinegar, spices and flavorings are added to it. These ingredients are added later during the boiling process to prevent the volatile oils from evaporating. This mixture is cooked for approximately 30-35 minutes during which they are constantly circulated by rotating blades in the kettles. Apart from cooking this is also the kill step in the process ensuring that the mixture is commercially sterile and free from pathogenic microorganisms. Once this process is completed the mixture is transferred into a finishing machine where excess fiber and particles are removed with the help of screens (11). Deaeration is performed in deaerators to prevent the growth of bacteria and discoloration. This mixture is now ready to be filled in containers; however, to prevent recontamination, a constant temperature above 88 degrees Celsius must be maintained (11). It is sealed immediately to retain freshness and, in the case of glass jars, to obtain a good vacuum seal. These containers are then cooled after which they are finally labelled and coded with product information. The standard ingredients in pasta sauce are tomato puree, which is tomato paste mixed with water, vegetable oil, sugar, spices and salt. According to the reports by Grand View Research, the global pasta sauce market is valued at USD 13.47 billion and is expected to grow at an annual growth rate of 3.2% from 2020 to 2027 (15, 21, 27). This growing popularity of pasta as a substitute for rice and other staple meals has proved to be a valuable factor in the growth of this industry. Packaged pasta sauce reduces the cooking time needed to collect and cook every single ingredient needed to prepare pasta sauce and makes pasta a quick and easy recipe. The popularity of fast-food chains such as Olive Garden and Maggiano has increased the consumer's interest towards the adoption of this delicacy. Freshness, low-sodium and organic are the prime attributes that consumers look for while making their selection. The key players in the pasta sauce market are Del Monte, Ragu, Barilla, Prego and Classico (15). Along with the impressive growing consumption levels, the pasta sauce industry also offers a selection of materials used to manufacture its packaging such as glass bottles, cans, PET, cartons and pouches. Amongst these, glass jars account for most of the market share.

EEasy Lids

Despite the huge market share of glass jars in the food industry, they are still inconvenient to open especially for the elderly and disabled community. After decades of hard to open lug type metal lids made of steel, CCT™ has developed a new generation of aluminum lids, with an innovative push button (Figures 1 and 2). The consumer applies a light push of the button located at the top of the lids to release the vacuum in the container, thereby significantly reducing the torque required to open the lid (8). The lids are available in both lug and continuous thread with sizes ranging from 58 to 82 mm similar to the standard lug cap (Figures 3 and 4). In their state-of-the-art facilities located in Dayton, Ohio, CCT (Figure 5) has the capacity to produce approximately 800 lids per minute, making it 250 million lids annually (9).

Figure 1: EEasy Lids: Top view.

Figure 2: EEasy Lids: Bottom View.

Figure 3: Standard lug lids: Top view.

Figure 4: Standard lug lids: Bottom view.

Figure 5: CCT headquarters in Dayton, Ohio.

According to the North Cliff report, a study done on EEasy lids with 79 panelists, 100% percent of the population found that the lids were easier to open compared to standard lids. Eighty nine percent of participants found the lid better than expected and said that they would purchase the jar with EEasy lids (21). This shows the clear market need for a revolution in the lid industry and that the EEasy lids would be a much-welcomed change to the standard lids. Another successful test performed by CCT was the Boyer case study where they partnered with Boyer's Food Markets and Stello Foods to develop the Darci's brand, a private label pasta sauce for the consumer market. The aim of this study was to serve as a proof of concept and to illustrate that easier to open jars drive sales (6). This was a 12-week case study performed from January to March 2020 which compared the sales of Darci's brand pasta sauce using EEasy lids to Brand A pasta sauce, which is a Boyer's private label brand. Both of the sauces were identical in terms of level of product, price and shelf space, the only differentiator being the EEasy lids on the Darci's sauce. The results of this study were phenomenal with the sales of Darci's lids increasing by 341% compared to previous year sales. Not only did Darci's brand pasta sauce outperform the Brand A, which it was being tested against, but it beat almost every other competitor which included national brands (6). For the food industry, aluminum vacuum closures and caps are imperative, and it is this need that drives the market. Recently, the FDA is promoting research and development to make the closures child resistant, convenient to use and senior friendly. EEasy lid's vision fits perfectly with this project and is set to be the first major jar lid innovation in over 75 years.

Project Objectives

This project studied the factors that influence the integrity of a hermetic seal for glass containers with metal lids used for shelf-stable foods. The influence of water activity, hot-pack temperature, and headspace on the vacuum measurements in glass closures were evaluated. In addition, the closure integrity of tomato sauce jars when using the new EEasy Lids was tested by measuring vacuum, removal torque, security and pull up values.

CHAPTER 2

Objective 1

Evaluation of the change in vacuum based on water activity in model foods packaged by hot packing into glass containers with metal closures.

Materials

- Standard 63 mm diameter lug lids with plastisol lining obtained from Giovanni Foods, Baldwinsville, New York
- Glass jars (24 oz) with lug finish obtained from Giovanni Foods, Baldwinsville, New York
- Food Grade Glucose from TLC Ingredients Inc, Crest Hill, IL

Methods

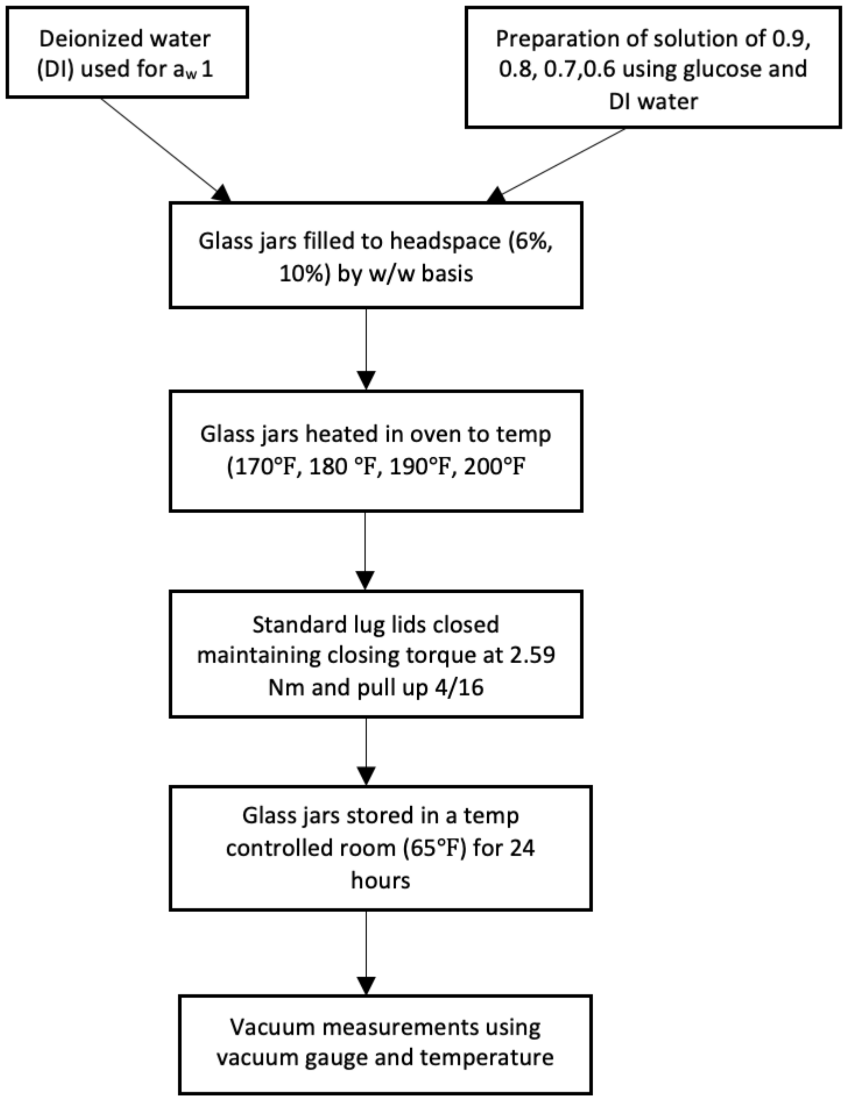

Figure 6: Process flow diagram for evaluation of vacuum in glass containers filled with glucose solutions based on water activity, headspace volume and hot-pack temperature.

Sample preparation for a_w of 1.0

Samples were prepared as described in Figure 6. Distilled water samples were used for glass jars with the a_w= 1. The headspace was measured using a weighing scale (Model Number:12007333, Sartorius Ag Gottingen, Germany) by weight-by-weight method. The weight of the glass jars was measured to be 326±1 g. When filled with distilled water up to the brim the weight of the jar was found to be 690.99g. Therefore for 6% headspace the weight was calculated to be 649.53 g and 621.0 g for 10% headspace. The tests were performed in triplicates for four hot pack temperatures- 170, 180, 190 and 200°F. These samples were heated in the Rational Self-Cooking Center (Model Number: SCC WE 201G, Rational Ag, Germany, Fig 8) until targeted temperature was reached after which they were closed, maintaining the closing torque using a torque meter (Model Number: 6A-061WU09, Nidec Shimpo Corp, China) at 2.59 N-m (23 lb-in) and a pull up of 4/16. These jars were then shifted to a temperature-controlled room kept at 68°F for 24 hours. The vacuum of the glass jars was measured using a manual vacuum gauge (0-30 in Hg, Waco, Wilkens-Anderson, Chicago IL) along with the sample temperature.

Sample preparation for a_w from 0.9 to 0.6

Glucose samples corresponding to water activities of 0.9, 0.8, 0.7 and 0.6 were prepared using pure glucose in powder form. The brix of the solution for the targeted water activity was calculated by trial and error using an AQUALAB Dew Point Water Activity Meter 4TE (Decagon devices, WA). To dissolve the sugar in the water external energy in the form of heat was required. The solutions were heated using a Cimarec heating plate (Barnstead Thermolyne Model Number: SP131325, Barnstead International, Iowa) and continuously stirred with a Barnant immersion

Mixer Series 10 (Model Number:700-5400, Barnant Company, Illinois). This was done until clear solutions were obtained (see Fig 7). For each water activity the headspace was measured using the weight-by-weight method. These samples were heated, capped and stored following the same procedure followed for a_w=1 samples. The vacuum of the glass jars was measured using the manual vacuum gauge along with the sample temperature (Fig 9).

Table 1: Soluble solids and headspace measurements for glucose solutions at different water activities using 24 oz glass jars.

Water Activity (a_w)	Soluble Solids (°Brix) ±0.01	100% W/W (g) ±0.01	6% headspace (g) ±0.01	10% headspace (g) ±0.01
0.90	47.20	823.44	774.03	741.10
0.80	61.85	855.07	803.70	769.56
0.70	78.50	861.05	809.38	774.94
0.60	81.50	913.50	858.00	822.00

Steam Flush Capping

The vacuum measurement decreases as the water activity decreases. To test the effect of steam flush capping on the vacuum levels, two samples of water activities 0.7 and 0.6 were chosen. The corresponding temperature and headspace were set at 10% and 180°F. As calculated in the above experiment, for water activity of 0.7 the brix was 78.50 and for 10% headspace the value was calculated to be 774.94 g. For 0.6 the brix was found to be 81.5 and 10% headspace was 822.00 g. Triplicates of each measurement were heated in the Rational Self Cooking Center (Model Number: SCC WE 201G, Rational Ag, Germany) to 180°F. These samples were then steam flushed using the single head steam capper (Model Number:59-300, Dillin, Ohio) at ~ 8 psi steam pressure (Fig10). The vacuum measurement was done after the samples cooled completely and compared to the vacuum measurements done with hot packed samples under the same temperature, water activity and headspace conditions.

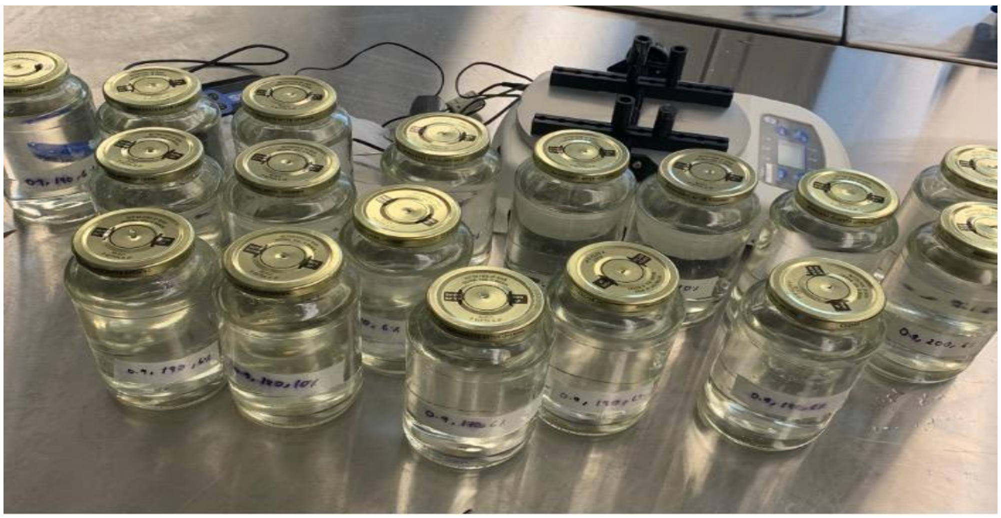

Figure 7: Glass jars filled with glucose solution at water activity of 0.9 prior to heating.

Figure 8: Heating samples in Rational Self Cooking Center.

Figure 9: Vacuum measurement using a manual vacuum gauge for a_w 0.8, 200 °F and 6% headspace.

Figure 10: Single Head Steam Capper.

Results and Discussion

The results of vacuum levels based on the factors evaluated are presented in Tables 2 through 7.

Table 2: Effect of temperature on vacuum measurements for hot-packed deionized water (a_w =1) in 24 oz glass jars with lug caps at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (in Hg)	Trial 2 (in Hg)	Trial 3 (in Hg)	Mean (in Hg)	Std Dev
170	6	12.5	12.5	11.5	12.2	0.6
180	6	15.5	15.0	15.0	15.2	0.3
190	6	17.0	17.5	17.3	17.3	0.3
200	6	17.5	17.5	17.0	17.3	0.3
170	10	12.0	11.5	11.5	11.7	0.3
180	10	14.0	14.0	14.0	14.0	0

190	10	15.5	15.5	14.0	15.0	0.9
200	10	16.0	17.5	17.5	17.0	0.9

Table 3:Effect of temperature on vacuum measurements for hot-packed glucose solution (a_w =0.9) in 24 oz glass jars with lug caps at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (in Hg)	Trial 2 (in Hg)	Trial 3 (in Hg)	Mean (in Hg)	Std Dev
170	6	11.5	10.5	10.5	10.8	0.6
180	6	11.5	11.5	11.0	11.3	0.3
190	6	13.0	13.5	13.0	13.2	0.3
200	6	14.0	14.0	14.0	14.0	0
170	10	10.0	10.5	10.0	10.2	0.3
180	10	11.0	11.0	11.5	11.2	0.3
190	10	11.5	11.0	12.5	11.7	0.8
200	10	13.5	13.5	14.0	13.7	0.3

Table 4: Effect of temperature on vacuum measurements for hot packed glucose solution (a_w=0.8) in 24 oz glass jars with lug caps at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (in Hg)	Trial 2 (in Hg)	Trial 3 (in Hg)	Mean (in Hg)	Std Dev
170	6	11.0	10.0	10.5	10.5	0.50
180	6	12.0	12.0	12.0	12.0	0

190	6	13.5	14.5	14	14.0	0.5
200	6	15.0	15.0	14.5	14.8	0.3
170	10	9.5	10.0	9.5	9.8	0.3
180	10	10.5	11.0	10.5	10.7	0.3
190	10	12.0	12.0	11.0	11.7	0.6
200	10	12.0	13.0	12.0	12.3	0.6

Table 5:Effect of temperature on vacuum measurements for hot packed glucose solution (a_w=0.7) in 24 oz glass jars with lug caps at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (in Hg)	Trial 2 (in Hg)	Trial 3 (in Hg)	Mean (in Hg)	Std Dev
170	6	9.5	8.5	9.5	9.2	0.6
180	6	9.5	10	9.5	9.7	0.3
190	6	10.5	10.5	10.5	10.5	0
200	6	10.5	11.0	11.0	10.8	0.3
170	10	7.5	7.5	6.5	7.1	0.6
180	10	7.5	8.5	8.5	8.1	0.6
190	10	9.0	9.5	9.5	9.3	0.3
200	10	10.0	11.0	9.7	10.3	0.7

Table 6: Effect of temperature on vacuum measurements for hot glucose solution (a_w=0.6) in 24 oz glass jars with lug caps at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (in Hg)	Trial 2 (in Hg)	Trial 3 (in Hg)	Mean (in Hg)	Std Dev
170	6	8.5	8.0	8.0	8.2	0.3

180	6	9.5	9.7	9.5	9.6	0.1
190	6	10.5	11.0	10.0	10.5	0.5
200	6	11.0	11.0	11.5	11.2	0.3
170	10	7.5	7.5	7.5	7.5	0
180	10	8.0	8.0	8.0	8.0	0
190	10	8.5	8.0	9.0	8.5	0.5
200	10	9.0	10.0	10.0	9.7	0.6

Table 7:Effect of steam flush on vacuum measurements at temperature 180 °F in 24 oz glass jars with lug caps at 6% and 10% headspace.

a_w	Headspace (%)	Trial 1 (in Hg)	Trial 2 (in Hg)	Trial 3 (in Hg)	Mean (in Hg)	Std Dev
1	6	19.5	19.5	19.0	19.3	0.3
1	10	18.5	18.0	18.0	18.1	0.3
0.7	10	16.5	16.0	16.5	16.3	0.3
0.6	10	15.0	14.0	15.0	14.7	0.6

Effect of hot-pack temperature on vacuum

The data obtained indicates that the vacuum in glass jars filled with heated solutions increases with the increase in temperature, as expected. This reaffirms that temperature and pressure have a direct proportional relationship (17). As the temperature increases in the liquid, the speed of their molecules increases which determines the kinetic energy and therefore, a higher relative humidity at the liquid surface, displacing the air in the headspace, resulting in a higher vacuum once the vapor condenses (18). Therefore, as we increase the temperature the vacuum in it increases. The presence of a good vacuum is an indication that the container seal is intact. Apart from the benefit of a good seal, the heating of the glass jar is an important kill step which to control food borne pathogens especially for high acid and water activity-controlled foods (26). A good vacuum also creates a low oxygen content inside the jar which is important to minimize the adverse chemical changes in the product such as changes in the vitamin and fat content, internal corrosion of the metal lids and discoloration of the food.

Effect of headspace on vacuum

Two headspaces, 6% and 10%, were chosen on a weight-by-weight basis to cover the recommended range for glass closures. According to the results, it was concluded that 6% headspace had a higher vacuum level compared to 10%. When the headspace is higher than required, the jar may not seal properly as there will not be adequate processing time to drive all the air out (11). This may also potentially lead to discoloration of the food at the top. If the headspace is less than required, the food may expand and bubble out when air is forced out from under the lid and prevent the jar from sealing properly (11). The headspace is dependent on the type of food that is stored in the jar. If the food swells and moves more inside the jar, the headspace needs to be greater. In the case of pasta sauce, there is more food material as well as higher viscosity compared to tomato juice and therefore would require more headspace.

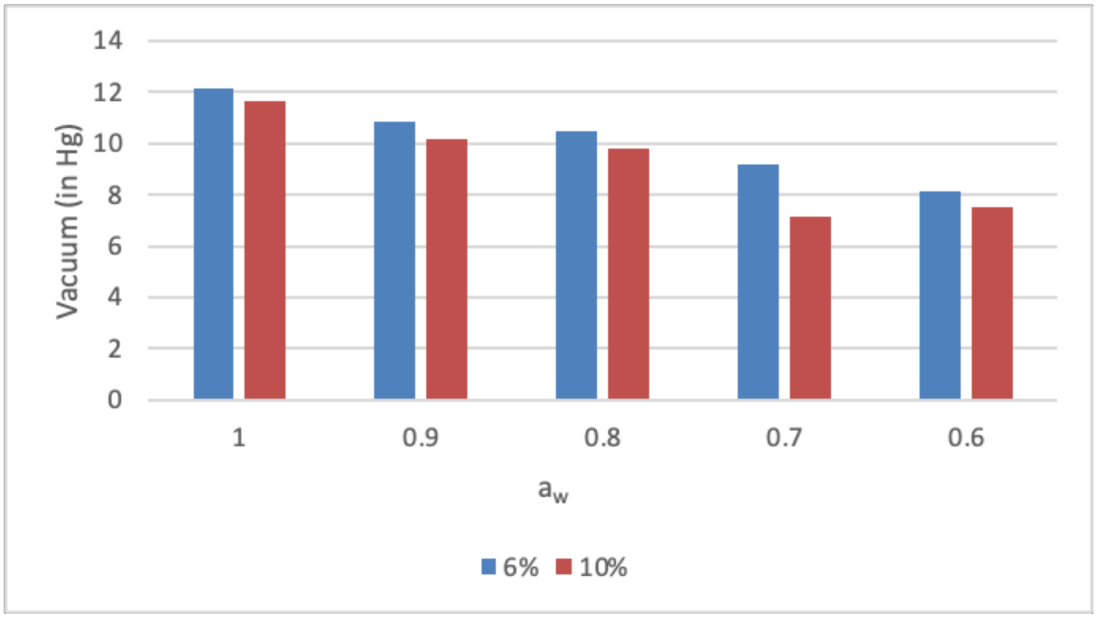

Figure 11: Comparison of vacuum measurements for hot-packed samples at 170 °F with 6% and 10% headspace.

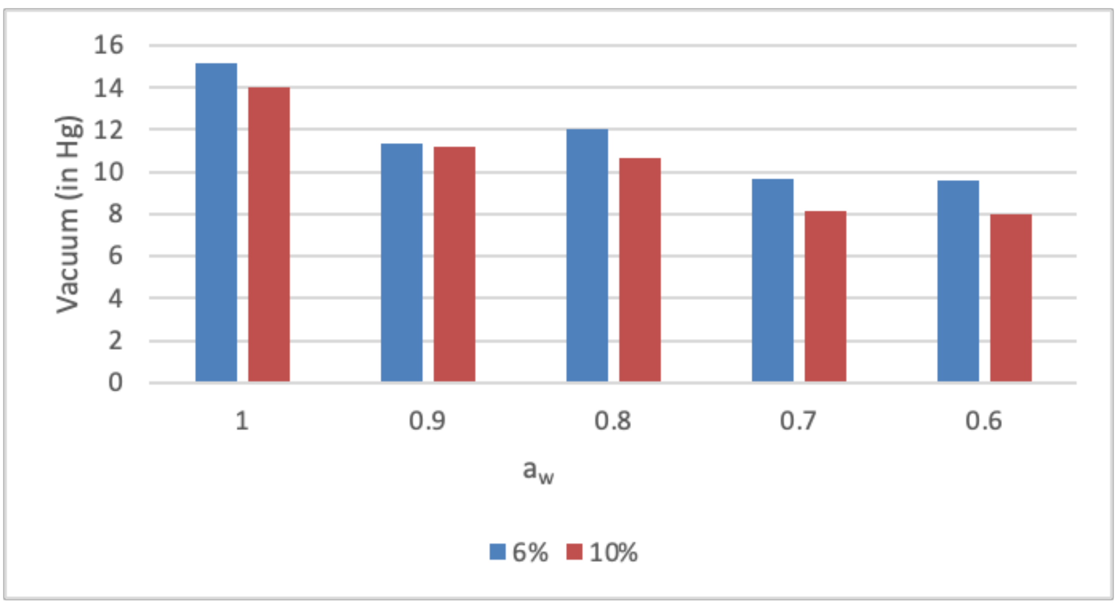

Figure 12: Comparison of vacuum measurements for hot-packed samples at 180 °F with 6% and 10% headspace.

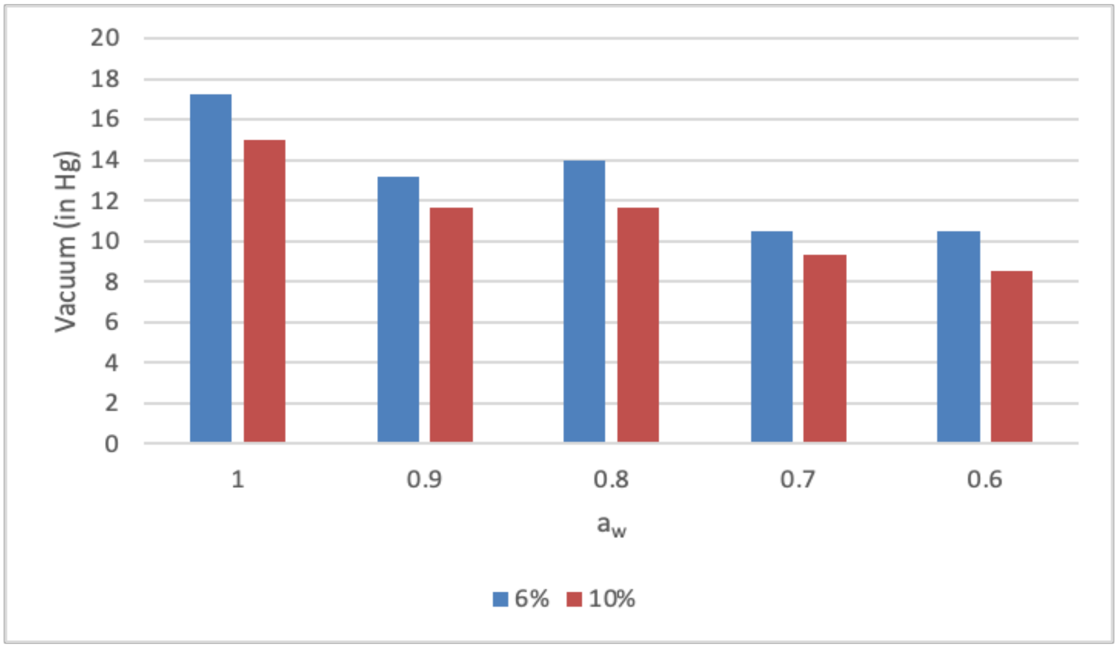

Figure 13: Comparison of vacuum measurements for hot-packed samples at 190 °F with 6% and 10% headspace.

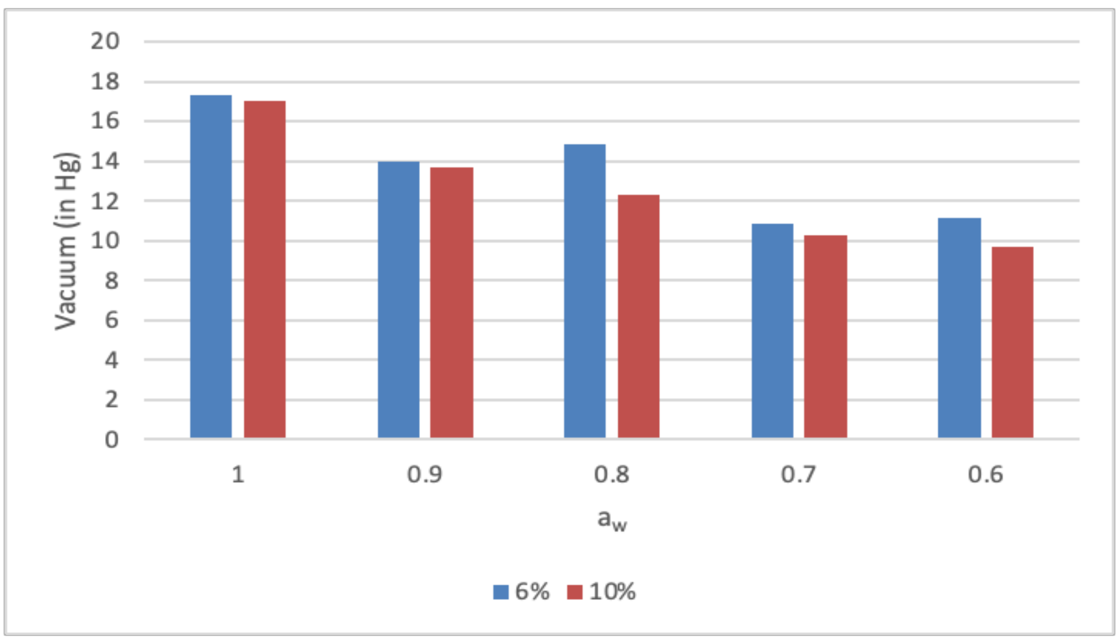

Figure 14: Comparison of vacuum measurements for hot-packed samples at 200 °F with 6% and 10% headspace.

Effect of steam flush capping on vacuum

Using steam flushing during capping of the jars led to a significant increase in the vacuum present in the jars (see Fig 15). In products with low water activity, where the vacuum formed during canning is low, steam flushing is a preferred alternative. For water activity of 1 the increase in vacuum for steam flush versus hot pack at 10% headspace was approximately 4 in Hg. The increase in vacuum for 0.7 and 0.6 a_w at 10% headspace was almost twice after the jar was steam flushed with an increase of approximately 6.5 in Hg.

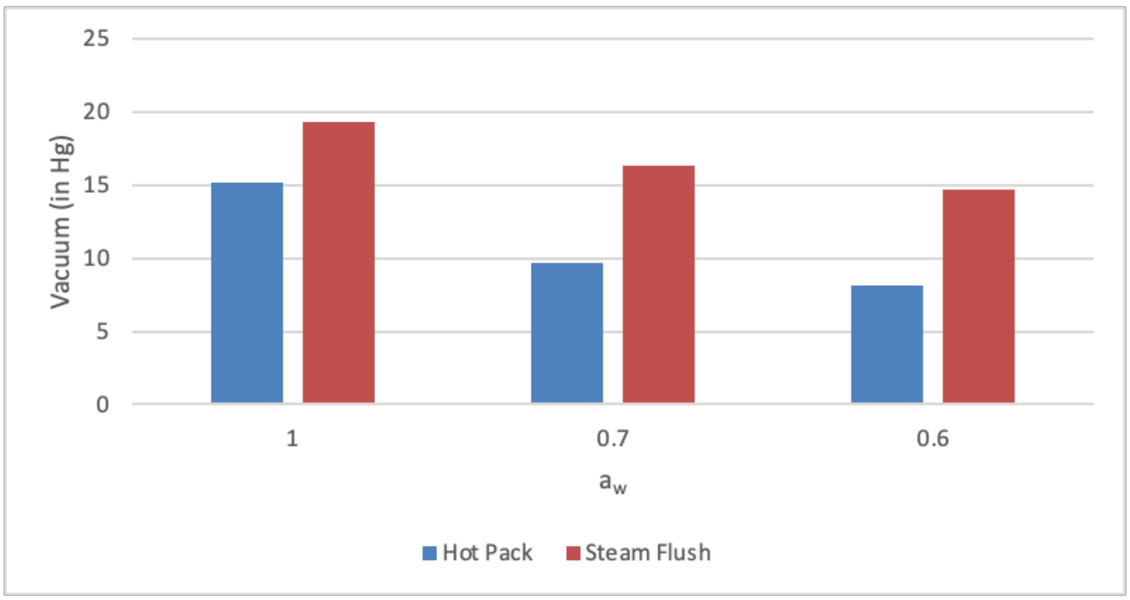

Figure 15: Comparison of vacuum for hot pack vs steam flush at 180 °F.

Conclusion

The water activity is one of the most important factors to consider when determining the food safety and shelf life of food products. The water activity also has a significant impact on the texture, flavor and aroma of the food. Most bacteria have a range below which they cannot survive and replicate. Water activity can be decreased in food through processes such as drying which physically removes water from the food, freezing where the water is removed in the form of ice or by adding solutes such as sugar and salt. In this study, glucose solutions were used as model foods to cover water activities from 0.6 to 1.0, representing most foods packaged in glass containers. The data obtained shows that as the water activity decreases, the vacuum developed in the glass jars by the process of hot packing decreases as well, allowing more oxygen to remain the headspace. Therefore, lower water activity foods will need processes such as steam flush to improve vacuum levels to obtain better seals and to prevent spoilage due to mold growth. The results from this study can serve as a reference point for the expected vacuum measurements for foods depending on their water activity, headspace and hot packing temperature.

CHAPTER 3

Objective 2

Compare the closure integrity performance of EEasy lids against the standard lug lids used by industry to hot-pack tomato sauce.

Materials

- Standard 63 mm diameter lug lids with plastisol lining obtained from Giovanni Foods, Baldwinsville, New York
- Glass jars (24 oz) with lug finish obtained from Giovanni Foods, Baldwinsville, New York
- Pasta sauce Gia Brands Inc, Boardman, Ohio supplied by Giovanni Foods, Baldwinsville, New York. The pH was 4.15, the Brix was 9.2 and the a_w 0.978.

- EEasy Lids (63 mm) obtained from CCT, Dayton, Ohio

Methods

To measure the integrity of the EEasy lids and compare it against the standard lug lids, the following test were performed: vacuum measurement, pull-up, security, removal torque, removal torque after pushing the button (EEasy Lids) and the change in vacuum after steam flush. All tests were performed in replicates of five to increase the statistical confidence. Pull up, security, gasket impression and removal torque measurements were performed in the same experimental unit.

Sample Preparation

Glass jars (24 oz) were filled with pasta sauce corresponding to 6% and 10% headspace. The headspace was calculated using the weight-by-weight method. The weight of the glass jar was measured to be 329±1 g using a weighing scale (Model Number:12007333, Sartorius Ag Gottingen, Germany). When filled with pasta sauce up to the brim the amount of pasta sauce was measured to be 735.0 g. Therefore for 6% headspace the amount of pasta sauce needed was calculated to be 690.9 g and 661.5 g for 10%. The test was performed in replicates of 5 for three hot pack temperatures - 180°F, 190°F and 200°F. These samples were heated along with the EEasy lids and standard lids in the Rational Self-Cooking Center (Model Number: SCC WE 201G, Rational Ag, Germany) to a higher temperature and allowed to cool until they reached the desired temperature (Fig 18). The amount of torque required for EEasy lids application was supposed to be 8-10 lb-in, based on CCT recommendations, which is significantly lower than standard lug lids (23 lb-in). After placing the glass jar in the torque meter (Model Number: 6A-061WU09, Nidec Shimpo Corp, China), EEasy lids was grasped using the thumb, index and ring finger to apply a torque of 8-10 lb-in with the help of the torque meter. The pull up should measure 4/16 inch to 8/16 inch from the mold line on the jar for proper application. Overtightening or stripping the lid will reduce the ability to seal the cap to the jar. Standard lids were closed maintaining a closing torque of 23 lb-in. These jars were then shifted to a temperature-controlled room kept at 66-68°F for 24 hours.

Vacuum Measurement

The vacuum of the glass jars was measured using a manual vacuum gauge (0-30 in Hg, Waco, Wilkens-Anderson, Chicago IL) by piercing the metal lid, along with the temperature.

Pull-Up Measurement

This is a visual inspection noting the position of the leading edge of the closure lug in correlation to one of the two vertical neck ring seam lines on the glass finish. The distance from the vertical line to the leading edge of the nearest cap lug is measured (see Fig 16). If the lug is positioned to the right side of the vertical neck ring seam, it is referred as positive and to the left side is referred to as negative (29).

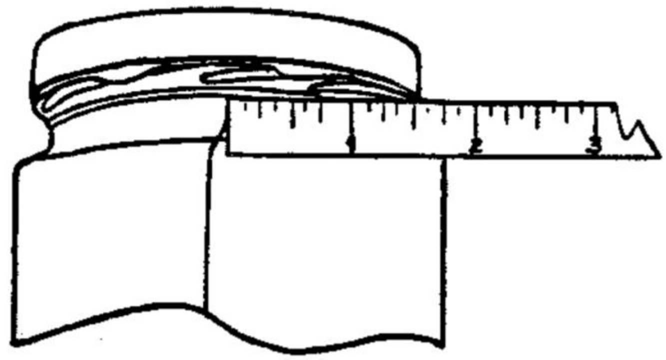

Figure 16: Pull-up measurement in a glass closure.

Security Measurement

A vertical line was marked using a marking pen on the cap and a corresponding line on the container (see Fig 17). The lids closure was turned counterclockwise until the vacuum was broken. The lid was then reapplied to the glass container just until the gasket compound touched the glass thread or until the closure was finger tight. The distance between the two vertical lines marked previously was measured in 1/16 in, corresponding to the security value. Security is considered positive if the line on the closure is to the right of the line on the container and vice versa (29).

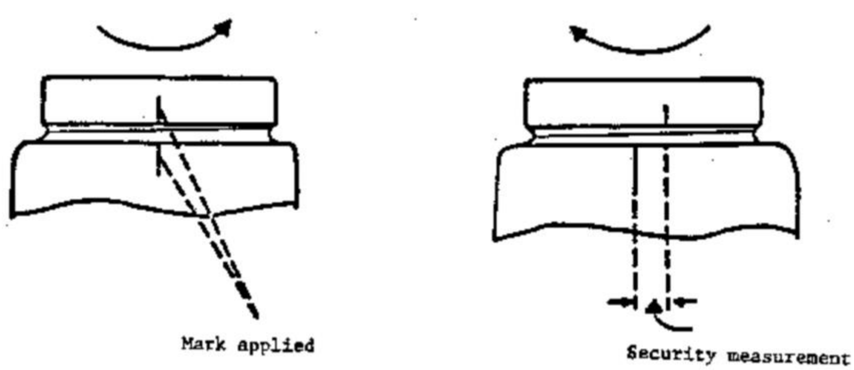

Figure 17: Security measurements in glass closures.

Removal Torque Measurement

Removal torque measurements for EEasy lids was performed both before and after pushing the center button on samples prepared as previously described. To measure the removal torque after the pushing the button, the glass jars were fixed on the torque meter. The button was pushed using the thumb until a pop sound was heard, then the torque was measured. For standard lug lids, and EEasy lids without pushing the button, removal torque measurements were done with the torque meter.

Gasket Impression

After the glass jar was opened and the cap was removed, the gasket was visually examined. There should be an even impression in the plastisol gasket all around the circumference.

Figure 18: EEasy Lids heated in oven soften plastisol.

Figure 19: Closing torque of 10 lb-in applied to EEasy Lids.

Figure 20: Glass jars with EEasy Lids after hot packing.

Results and Discussion

The function of lids in a glass jar is to create an absolute barrier between the stored food and the environment thus preventing the entry of microorganisms and gaseous exchange inside the jar. The pasta sauce industry which is growing rapidly is one of the main markets for glass closures and with it comes the need to have packaging that is sustainable and inclusive. To inspect the efficiency of EEasy Lids, both non-destructive and destructive tests were performed. The temperature range chosen for the measurement was 180-200 °F which is the canning temperature used to destroy most bacteria, yeast and molds in acid foods. The results of closure integrity evaluation of EEasy Lids compared to standard lug lids are presented in Tables 8 through 16.

Comparison of Vacuum

Table 8: Effect of temperature on vacuum measurements for hot packed pasta sauce in 24 oz glass jars with EEasy lids at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (in Hg)	Trial 2 (in Hg)	Trial 3 (in Hg)	Trial 4 (in Hg)	Trial 5 (in Hg)	Mean (in Hg)	Std Dev
180	6	No vacuum	8.0	6.0	No vacuum	9.0	7.7	1.5
190	6	10.0	9.0	9.0	8.0	No vacuum	9.0	0.8
200	6	No vacuum	12.0	9.0	8.0	9.0	9.5	1.7
180	10	7.0	6.0	7.0	6.0	6.0	6.4	0.5
190	10	8.0	6.0	6.0	6.0	6.0	6.4	0.9
200	10	7.0	6.0	8.0	9.0	9.0	7.8	1.3

Table 9: Effect of temperature on vacuum measurements for hot packed pasta sauce in 24 oz glass jars with standard lug lids at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (in Hg)	Trial 2 (in Hg)	Trial 3 (in Hg)	Trial 4 (in Hg)	Trial 5 (in Hg)	Mean (in Hg)	Std Dev
180	6	12.5	12.5	12.0	12.7	12.5	12.6	0.3
190	6	13.0	13.0	13.0	13.7	13.0	13.2	0.3
200	6	15.5	15.0	14.7	14.5	14.5	14.9	0.4
180	10	7.0	7.0	7.0	7.0	7.0	7.0	0
190	10	7.5	8.0	8.0	8.5	8.0	8.0	0.4
200	10	9.0	9.5	9.0	9.5	9.5	9.3	0.3

From the data obtained it can be noticed that as the temperature increases the vacuum values increase which is according to the expectation from the results obtained in Objective 1. The vacuum values for 6% headspace were higher compared to 10% headspace for both EEasy Lids and standard lids. The use of correct headspace and proper tightening allows for a good vacuum. A higher vacuum represents lower retained oxygen which is associated with better quality during storage period (25). Filled jars while cooling naturally contract and pull the lid down, leading to a good seal. Low vacuum may lead to discoloration of food and rancidity of fats due to the presence of oxygen in the headspace. The results for vacuum for EEasy Lids were significantly lower than standard lids, likely due to closing torque applied for EEasy Lids (8-10 lb-in which was found to be too low) to get a good hermetic seal. In some samples, vacuum was not achieved. It is proposed that EEasy lids increase their suggested closing torque to approximately 15-18 lb-in. The mean brix of the Gia Brand Pasta sauce was 9.3, pH of 4.15 and a_w of 0.978. Comparing this with the vacuum values calculated for similar water activity in objective 1, it can be noticed that the vacuum values are close to the expected values for 6% headspace but lower at 10% headspace when pasta sauce is used for standard lids.

Comparison of Removal Torque

Table 10: Removal torque for 24 oz hot packed tomato sauce jars with EEasy Lid with pressed button at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (lb-in)	Trial 2 (lb-in)	Trial 3 (lb-in)	Trial 4 (lb-in)	Trial 5 (lb-in)	Mean (lb-in)	Std Dev
180	6	9.7	15.8	12.5	19.0	18.1	15.0	3.9
190	6	15.0	11.6	13.7	11.9	17.9	14.0	2.6
200	6	13.3	19.2	12.7	10.6	14.0	13.9	3.2
180	10	8.5	10.0	15.2	13.2	11.0	11.6	2.6
190	10	11.8	13.0	13.1	15.0	16.4	13.9	1.8
200	10	15.0	14.7	14.0	9.0	15.3	13.6	2.6

Table 11:Removal torque 24 oz hot packed tomato sauce jars with EEasy lid without pressing button at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (lb-in)	Trial 2 (lb-in)	Trial 3 (lb-in)	Trial 4 (lb-in)	Trial 5 (lb-in)	Mean (lb-in)	Std Dev
180	6	20.5	24.1	26.6	26.0	29.0	25.2	3.2
190	6	24.0	26.7	23.1	27.0	18.6	23.9	3.4
200	6	24.3	27.8	21.8	25.0	29.0	25.6	2.9
180	10	18.1	22.9	18.3	21.3	27.0	21.5	3.7
190	10	23.0	20.3	22.6	29.0	25.0	23.9	3.3

200	10	25.0	21.6	24.8	23.0	29.4	24.8	2.9

Table 12: Removal torque for 24 oz hot packed tomato sauce jars with standard lug lid at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (lb-in)	Trial 2 (lb-in)	Trial 3 (lb-in)	Trial 4 (lb-in)	Trial 5 (lb-in)	Mean (lb-in)	Std Dev
180	6	18.9	17.8	18.3	18.9	19.0	18.6	0.5
190	6	20.8	20.5	21.2	20.1	22.0	20.9	0.7
200	6	23.7	21.7	21.8	22.3	22.9	22.5	0.8
180	10	22.0	23.0	23.0	23.0	25.0	23.2	1.0
190	10	31.0	27.0	29.0	27.0	28.0	28.4	1.7
200	10	24.0	24.5	24.0	29.0	25.0	25.3	2.1

From the data obtained it can be clearly noticed that the opening torque needed to open glass jars with EEasy lids after pressing the button is significantly lesser than standard lug lids presently in the market. Comparing the means for the torque values of EEasy lids and standard lug lids, a minimum reduction of 28% and maximum of 51% was observed for EEasy Lids. Without the pressed button, the removal torque values are similar for both. The removal torque values increased with the increase in hot-packed temperature due to the higher vacuum formed in the glass jars. However, the data obtained shows a high variability (standard deviation) in removal torque measurements for EEasy Lids compared to standard lug lids. This can be improved by vacuum measurements which are uniform for a specific set of conditions (headspace and temperature).

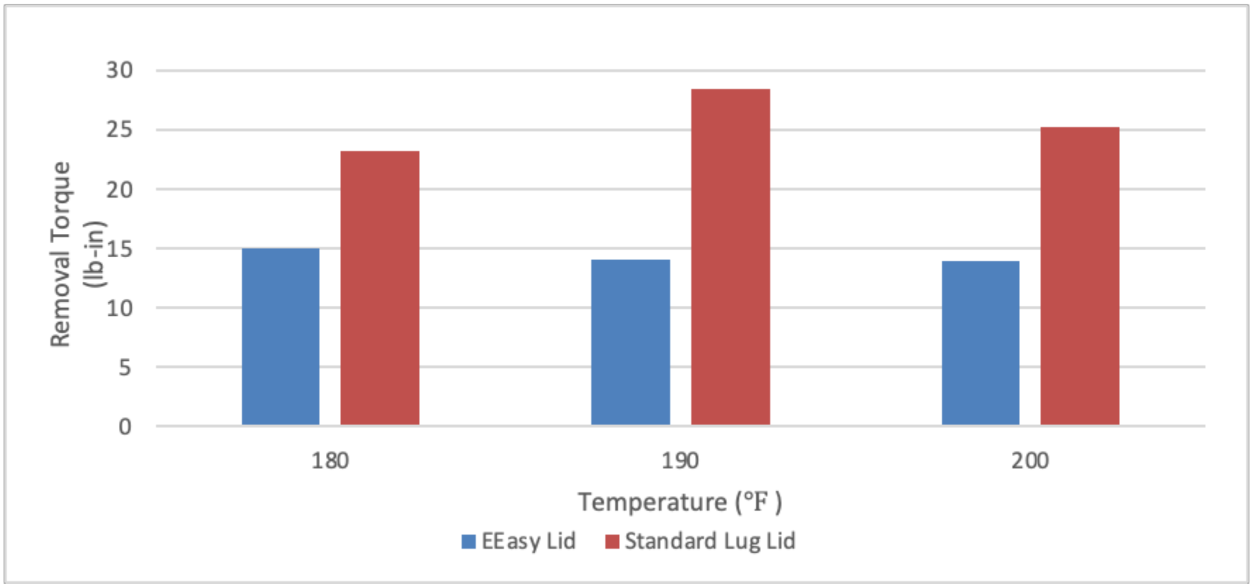

Figure 21: Comparison of removal torque between EEasy Lids and Standard Lid at 6% headspace.

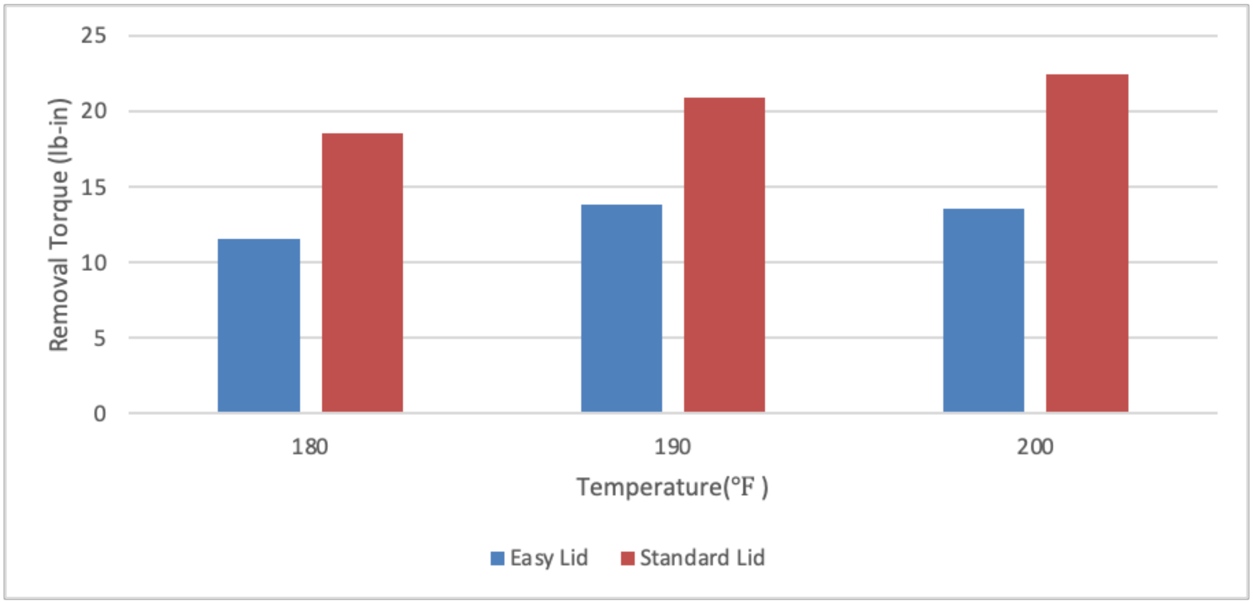

Figure 22: Comparison of removal torque between EEasy Lids and Standard Lid at 10% headspace.

Security Values

Table 13: Security values for hot packed pasta sauce in 24 oz glass jars with EEasy Lids at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (1/16 in)	Trial 2 (1/16 in)	Trial 3 (1/16 in)	Trial 4 (1/16 in)	Trial 5 (1/16 in)
180	6	+1	+1	+1	0	+1
190	6	+1	+1	+1	+1	0
200	6	+1	0	+1	+1	0
180	10	+1	0	+1	+1	+1
190	10	-1	+1	+1	+1	+1
200	10	0	+1	+1	+1	+1

Table 14: Security values for hot packed pasta sauce in 24 oz glass jars with standard lug lids at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (1/16 in)	Trial 2 (1/16 in)	Trial 3 (1/16 in)	Trial 4 (1/16 in)	Trial 5 (1/16 in)
180	6	+1	+1	+1	+1.5	+1
190	6	+1	+1.5	0	1.5	1
200	6	+1	+1	+1	+1	+1
180	10	+1	+1	+1	0	+1
190	10	+1	+1	+1	+1	+2
200	10	+2	+2	+1.5	0	1

The security values obtained for both EEasy Lids and standard lids are within the range required to have a good seal. A positive value is reported if the line on the cap is to the right of the line on the container and negative if the line is on the left of the container line. Since no high positive values or negative values are obtained which could indicate under-application or over-application, no corrective action must be taken.

Pull-Up Values

Table 15: Pull-Up values for hot packed pasta sauce in 24 oz glass jars with EEasy Lids at 6% and 10% headspace.

Temp (°F)	Headspace (%)	Trial 1 (in)	Trial 2 (in)	Trial 3 (in)	Trial 4 (in)	Trial 5 (in)
180	6	11/16	10/16	13/16	13/16	13/16
190	6	11/16	12/16	11/16	13/16	11/16
200	6	11/16	13/16	10/16	12/16	12/16
180	10	14/16	10/16	13/16	11/16	11/16

190	10	14/16	15/16	11/16	11/16	14/16
200	10	13/16	11/16	13/16	12/16	15/16

Table 16: Pull-Up values for hot packed pasta sauce in 24 oz glass jars with standard lid at 6% and 10% headspace

Temp (°F)	Headspace (%)	Trial 1 (in)	Trial 2 (in)	Trial 3 (in)	Trial 4 (in)	Trial 5 (in)
180	6	4/16	3/16	3/16	4/16	5/16
190	6	3/16	3/16	3/16	3/16	3/16
200	6	4/16	4/16	3/16	3/16	3/16
180	10	3/16	4/16	4/16	4/16	4/16
190	10	4/16	3/16	3/16	4/16	4/16
200	10	3/16	3/16	3/16	4/16	4/16

Gasket Impression

Figure 23: Gasket Impression of EEasy Lids.

Figure 24: Gasket Impression of Standard Lids

The gasket impression for EEasy Lids was not as deep compared to standard lids. The gasket is the part of the lid that makes intimate contact with the glass finish at a specific point, forming a good hermetic seal. This could again indicate that the EEasy Lids needs to be closed with higher application torque than what was originally recommended by the manufacturer.

Conclusion

Glass jars are the most widely used packaging for pasta sauce which has a water activity of approximately 0.97 which is high and is susceptible to microbial spoilage. The pH of approximately 4.15 makes pasta sauce an acid food and offers a degree of protection to it. EEasy lids is a major innovation in the lid industry which significantly decreases the torque required to open a glass jar. The adoption of this type of lid for common food products packed in glass containers, such as tomato sauce will be a positive step towards making packaging more inclusive for the elderly and disabled. It works by pressing the button on the lid to break the vacuum, and the jar can be reclosed by pressing the button from the inside maintaining freshness during refrigerated storage.

Our results demonstrated that compared to standard lug lids currently present in the market, EEasy Lids were significantly easier to open with a removal torque measurement reduced by 28-51% depending on vacuum level. Headspace of 6% led to higher vacuum values compared to 10% headspace for both EEasy Lids and standard lids. This could be due to more retention of air in the jar at the larger headspace. Increasing the temperature at which the jars were hot packed increased the vacuum measurements inside the glass jars similar to the results observed in objective 1.

The data obtained for vacuum measurements were not within range and had a high degree of variability compared to standard lids. A closing torque of 8-11 lb-in suggested by the manufacturer is significantly lower than the 23lb-in torque needed for standard lug lids. To ensure a good hermetic seal, additional testing needs to be done to determine the proper range for closing torque. The high pull-up values, which is a non-destructive method to ensure the engagement between lugs and the finish further adds to our conclusion that the engagement was not tight enough affecting the final seal.

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