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# New Aluminum Lug Closure Reduces Removal Torque while Ensuring Hermetic Seals in Glass Jars

## ABSTRACT

The development and introduction of a vacuum release aluminum (VRA) lug closure into the glass jar market constitutes an important innovation in the food packaging industry by significantly reducing the torque needed to remove the lid from the glass jar, thus facilitating jar opening by consumers. The new lids were compared with the industry standard, steel lug closures, for sealing performance and torque removal. Closure of glass jars hot-packed with deionized water was evaluated by measuring pull-up, vacuum, security, and removal torque. The effects of hot-pack temperature from 82 to 93°C and headspace at 6 and 10% on the integrity and opening of glass closures were studied. Jars packed with tomato sauce and capped with both types of lids were evaluated for ease of opening by measuring removal torque. Performance of the new VRA lug lids was similar to that of the standard lids for all parameters measured except removal torque. Removal torque values for jars sealed with VRA lids were 20 to 51% lower than those for the standard lids.

## INTRODUCTION

Food packaging performs the basic function of containing the food and plays a major role in protecting the food against physical damage, entry of microorganisms, physiochemical degradation, and possible tampering. Appropriate packaging helps to maintain the nutritional quality, safety, and expected shelf life. Many packaging materials are safe to use in food applications: metal, glass, plastic polymers, and paper. Glass containers have a long history in food packaging, with the first recorded incidence around 3,000 BC. Packaging production involves the heating of materials, including sand, limestone, soda ash, and recycled glass, at very high temperatures >1,425°C (2,600°F) to reach the melting point. The molten material can be poured into molds to form the desired shape and size by blow molding *(3)*.

The glass container has three basic parts: finish, body, and bottom *(7)*. The finish is the top part of the glass container, which incorporates the opening and engages with the closure or lid. The three general types of finishes are lug, press-on/twist-off, and continuous thread. The Glass Packaging Institute has set standards for dimensions and specifications

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for each type of finish, allowing manufacturers and suppliers to work with a variety of containers while maintaining the integrity of the finish and closure. The metal closures or lids are commonly made from tinplated steel or tin-free steel, depending on the type of food product packaged. For further protection of the metal under corrosive conditions, such as when packing acidic foods, organic coatings may be applied to the internal and external surfaces of the caps. The coating must be compatible with the food and enable the application of the plastisol gasket material *(3)*.

The lug closure, also known as twist cap, is widely used in the food industry because of the high speed achieved during application, because this lid needs only a partial turn. The lid provides a secure hermetic seal that can be opened by hand and resealed by the consumer for further use. The lids have a metal shell with a straight or fluted skirt and may have a safety button *(3)*. Depending on the type of lid, there can be three to eight lugs that engage with the glass lugs of the container, and the lid diameter ranges from 27 to 110 mm. The lids are lined with plastisol to provide a hermetic seal that can hold a vacuum. The closures need to be inspected at regular intervals to ensure the integrity of the seals *(2)*.

Based on U.S. Food and Drug Administration canning regulations *(11)*, shelf-stable, hermetically sealed food containers must be inspected to ensure seal integrity. For glass jars, the inspection program should include a visual examination and a destructive (tear down) examination for defects that could affect product and/or package integrity. The visual examination should be made at intervals not >30 min, and the destructive evaluations should be conducted at intervals not >4 h. Visual examinations for lug closures include checking for obvious defects, misapplication of cap, lid concavity indicating vacuum, and pull-up. Pull-up is a visual check to measure the fit of the closure lugs on the lugs of the glass jar and is defined as the "distance between the leading edge of the cap lug and the vertical neck ring seam on the glass finish" *(3)*. Destructive evaluations include measurement of vacuum, fill temperature, headspace, gasket impression, removal torque, and security. Security, defined as the lug tension of an applied closure, is the most dependable measurement to ensure a good seal for lug closures. Adequate pull-up and security values per type of container are specified by the closure manufacturer *(2)*.

For canned foods packaged in glass containers with metal lids, the presence of vacuum ensures that a hermetic seal has been achieved. A visual indication of vacuum to the consumer is the depressed safety button, located in the center of the lid, which also helps to indicate low- or no-vacuum packages in automatic operations *(1)*. The factors affecting vacuum formation are headspace, product sealing temperature, air in the product, and capper vacuum efficiency when cappers are used. The required headspace differs with the type of product, but a general rule of thumb is 6 to 10% of the container volume. Keeping all the other factors constant, the higher the product temperature is at the time of sealing, the stronger the vacuum will be after cooling. The air in the product should be kept at a minimum to ensure a good seal, product appearance, and product quality because oxygen in the air will accelerate rancidity, browning, and loss of nutrients *(3)*.

The standard lug type metal lids made of steel can be hard to open; thus, a new generation of aluminum lids was developed with a push button *(Fig. 1)*. The consumer applies a firm push to the button located at the top of the lid to release the vacuum in the container, thereby significantly reducing the torque required to open the lid. The aluminum lid was designed with the required strength to maintain closure integrity throughout the shelf life of the packaged food. If vacuum were accidentally lost, the lid would lose concavity, similar to standard lug lids, indicating to the consumer that the seal is compromised. The new vacuum release aluminum (VRA) lug lids were designed to facilitate opening of a glass jar by all consumers, including the elderly and physically impaired individuals *(4)*. One of the main markets for glass jars is the tomato sauce industry. According to a report by Grand View Research *(6)*, the global pasta sauce market is valued at USD 13.47 billion and is expected to grow at an annual rate of 3.2% from 2020 to 2027. This market segment is one of the main users of glass closures and must have packaging that is sustainable and inclusive.

This study was focused on evaluating the performance of VRA lug lids versus standard lug lids to render hermetically sealed glass jars. To assess the proper application of the new and regular lug lids, both nondestructive and destructive tests were performed. The closure integrity on jars filled with deionized water was tested by measuring pull-up, vacuum, removal torque, and security. Main factors affecting vacuum formation, such as hot-pack temperature and headspace, were studied. Jars packed with tomato sauce and capped with both lids also were evaluated for ease of opening by measuring removal torque.

## MATERIALS AND METHODS

### Sample preparation

Glass jars (24 oz 710 ml) with lug finish and standard lug lids (63 mm in diameter) with plastisol lining were obtained from Giovanni Foods (Baldwinsville, NY). VRA lug lids of the same diameter were obtained from Consumer Convenience Technologies (EEASY Lids, Dayton, OH). Both standard and VRA lug lids had the same number of metal lugs and same plastisol lining materials, as shown in *Figure 1*.

Sample jars were prepared based on the procedures listed in *Figure 2*. Jars were filled leaving either 6 or 10% headspace. The headspace was calculated using the weight-by-weight method. The weight of the glass jar was 329 ± 1 g, as determined with a scale (model 12007333; Sartorius Ag, Gottingen, Germany). When filled with deionized water up


FIGURE 1. Face (top) and reverse (bottom) of standard lug and vacuum release aluminum (VRA) lug lids evaluated.

to the brim, the weight of the jar was 691.0 g. Therefore, the weight of water was calculated to be 649.5 g for 6% headspace and 621.0 g for 10% headspace. When filled with pasta sauce up to the brim, the amount of pasta sauce was 735.0 g. Therefore, the amount of pasta sauce was calculated to be 690.9 g for 6% headspace and 661.5 g for 10% headspace.

The tests for deionized water jars were performed in triplicate by preheating jars with hot water to 49°C. Hot water at 82, 88, and 93°C was placed into preheated jars leaving 6 and 10% headspaces. For VRA lids, the jars were closed manually to a pull-up value of 4/16 in (6.35 mm), and the closing torque was measured with a torque meter (model 6A-061WU09; Nidec Shimpo Corp., Glendale Heights, IL). The pull-up should measure at 4/16 to 8/16 in (12.7 mm) from the mold line on the jar for proper application. For standard lug lids samples, the jars were applied to 23 lb-in (2.59 N m) of torque manually, as determined with a torque meter, according to the supplier's specification. These jars were then held for 24 h in a temperature-controlled room kept at 19 to 20°C.

The test for tomato sauce jars was performed with five replicates for the three hot-pack temperatures of 82, 88, and 93°C. The tomato sauce samples were heated with the VRA and standard lids in the Rational Self-Cooking Center (model SCC WE 201G; Rational Ag, Landsberg am Lech, Germany) to a higher temperature and allowed to cool until they reached the targeted temperature. The tomato sauce jars were closed manually with VRA and standard lug lids with the same method as used for the deionized water jars. These jars were then held for 24 h in a temperature-controlled room kept at 19 to 20°C.

### Vacuum measurement

The vacuum of the deionized water jars was measured with a manual vacuum gauge (0 to 30 in Hg; Waco, Wilkens-Anderson, Chicago, IL) by piercing the metal lid of the sealed glass jars *(Fig. 3)*.

### Pull-up measurement

The pull-up values of deionized water jars were measured by visual inspection, noting the position of the leading edge of the closure lug in relation 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 *(Fig. 4)*. Lugs to the right side of the vertical neck ring seam are referred to as positive, and lugs to the left side are referred to as negative *(2)*.

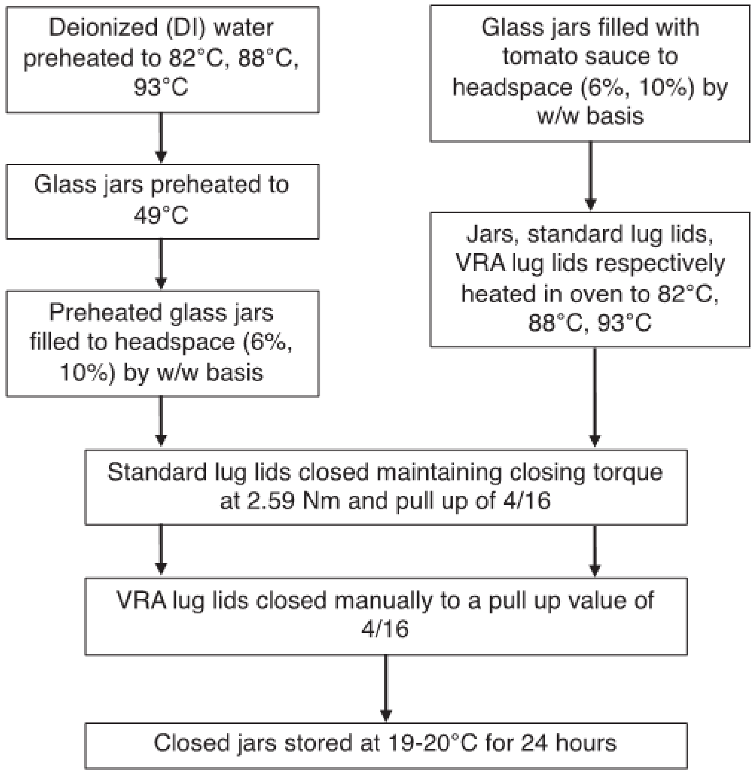


**FIGURE 2. Process flow diagram for vacuum closure evaluation of glass containers filled with deionized water and tomato sauce based on headspace volume and hot-pack temperature.**


**FIGURE 3. Vacuum measurement obtained by piercing the metal lid with a vacuum gauge.**

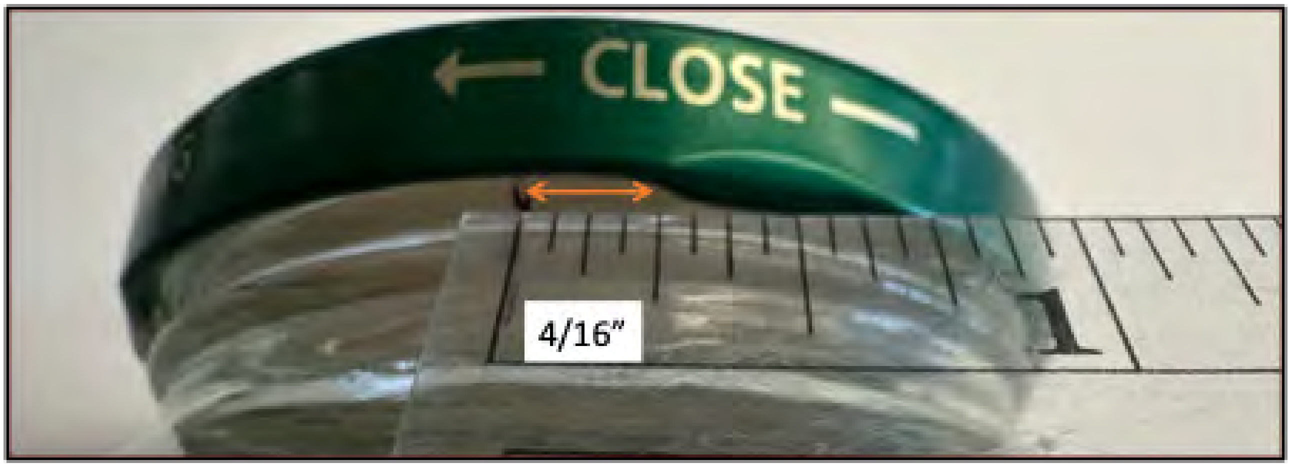


FIGURE 4. Pull-up measurement for a glass jar with a metal lug closure.

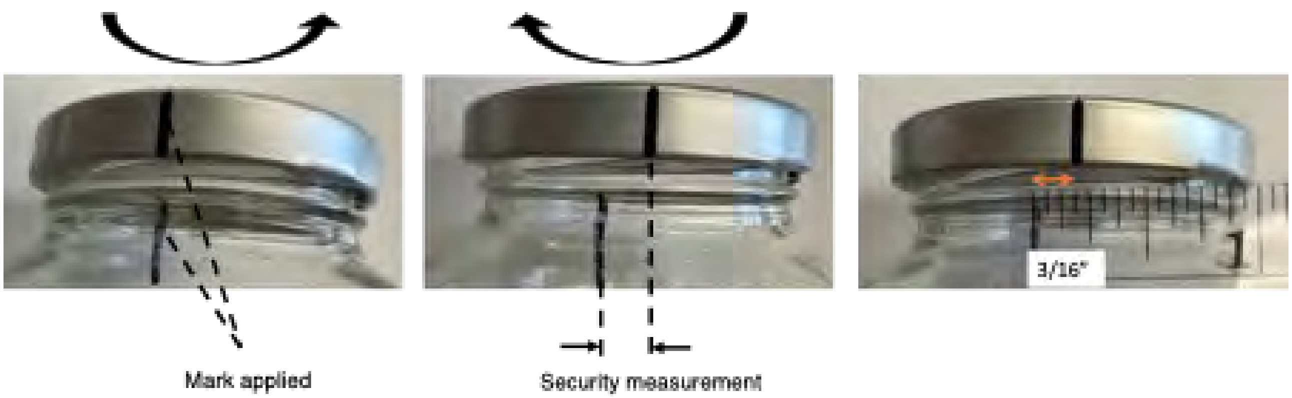


FIGURE 5. Security measurement for a glass jar with a metal lug closure.

**Security measurement**

A vertical line was marked with a marking pen on each lid, and a corresponding line was marked on the jar *(Fig. 5)*. The lid closure was turned counterclockwise until the vacuum was broken. The lid was then reapplied to the jar 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 (1.6 mm), corresponding to the security value. The security values of deionized water jars were measured.

**Removal torque measurement**

Removal torque for VRA lug lids was measured both before and after pressing the center button on jars prepared as previously described. To measure the removal torque after 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 for VRA lug lids for which the button was not pushed, removal torque was measured with the torque meter. The removal torque values of glass jars containing deionized water and tomato sauce both were measured.

**Statistical analysis**

Water samples were tested in triplicate per experimental condition. Tomato sauce samples were prepared in five replicates for removal torque measurements. Results were evaluated using Tukey's honestly significant difference test, and differences were considered significant at the 95% confidence level.

## RESULTS AND DISCUSSION

**Effect of hot-pack temperature and headspace on pull-up and security values**

The hot-pack temperature range chosen for the measurements was 82 to 93°C, which represents canning temperatures typically used to render acid and acidified foods commercially sterile by destroying pathogenic and spoilage

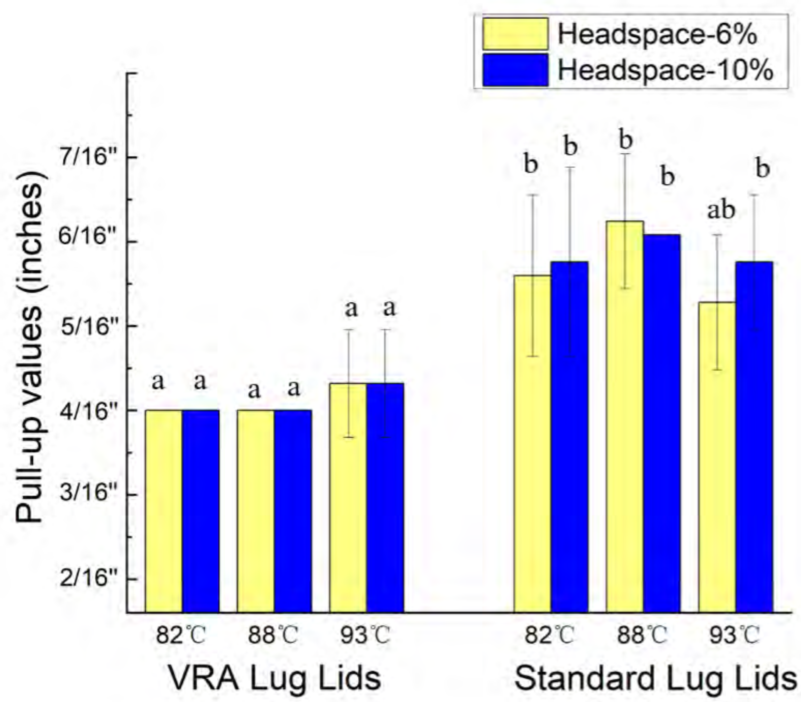


**FIGURE 6. The pull-up values of hot-packed deionized water in glass jars sealed with vacuum release aluminum (VRA) lug lids and standard lug lids with headspaces of 6 and 10%. Pull-up values are in 1/16 in (1.57 mm). Values of bars with the same letters are not significantly different at *P* < 0.05.**

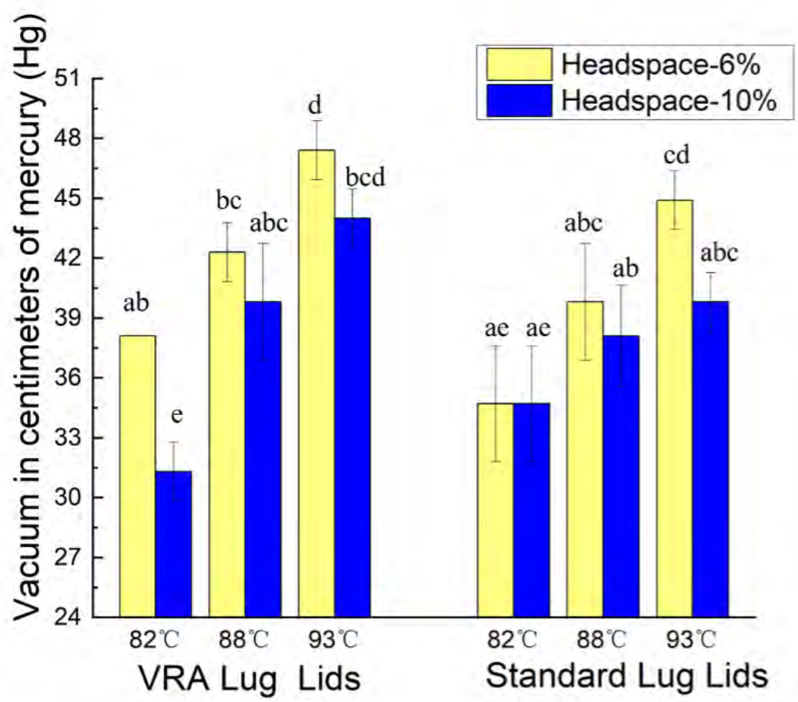


**FIGURE 7. Vacuum of hot-packed deionized water in glass jars sealed with vacuum release aluminum (VRA) lug lids and standard lug lids with headspaces of 6 and 10%. Values of bars with the same letters are not significantly different at *P* < 0.05.**

microorganisms able to grow under normal distribution conditions. High pull-up values (significantly >6/16 in [9.5 mm]) indicate that the engagement is not tight enough, affecting the final seal. Overtightening or stripping the lid will reduce the ability to seal the lid to the jar, which could represent a pull-up value <2/16 in (3.2 mm) or even reach a negative number *(3)*. Samples with VRA lug lids had a uniform pull-up value of 4/16 in *(Fig. 6)*. The average values for jars with standard lug lids samples (individual measurements were 4/16 to 7/16 in [6.3 to 11.1 mm]) were higher except for the sample filled at 93°C with 6% headspace. Because the standard lug lids were applied to a target torque of 2.59 N m, minor variations in the pull-up values were expected. Jars with VRA and standard lug lids had proper closure applications; the pull-up values were within the normal operating range of 4/16 to 7/16 in *(2)*.

The security value is the most important measurement for proper application of a lug closure. A positive value is reported when the line on the cap is to the right of the line on the container, and a negative value is reported when the line is on the left of the container line. A value higher than the range specified by the manufacturer indicates over- or underapplication , respectively *(2)*. The security values obtained for both lids were within the normal positive range to have a secure seal of 4/16 to 6/16 in. No significant differences were found based on type of lid, hot-packing temperature, or headspace. Because no high positive or negative values were observed, which could indicate under- or overapplication, the performance of the VRA lug lids was similar to that of the standard lids, resulting in adequate closure application under the conditions tested in the present study.

**Effect of hot-pack temperature and headspace on vacuum**

The results of the evaluation of the closure integrity of VRA lug lids compared with standard lug lids are presented in *Figure 7*. The vacuum in jars sealed with both types of lids increased with the rise of the hot-pack temperature at both headspace conditions evaluated. These results confirmed that temperature and internal pressure have a direct proportional relationship. As the temperature increases, the liquid expands and more steam is present at the liquid surface, decreasing the volume of air in the headspace and creating a higher vacuum once the vapor condenses and the liquid volume decreases after cooling *(5)*. Therefore, as the water temperature during hot-packing increases significantly, the vacuum in the sealed jar at room temperature will also increase under proper headspace values. 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 by the hot liquid or food constitutes an important commercial sterilization step to control foodborne pathogens and spoilage microorganisms, especially for high-acid and water activity-controlled foods that are manufactured by hot-packing *(8)*. A good vacuum also creates a low-oxygen environment inside the jar, which will minimize adverse changes in the product such as changes in vitamin and fat contents, internal corrosion of the metal lid, and discoloration of the food *(10)*.

Two headspaces, 6 and 10%, were chosen on a weight-by-weight basis to cover the recommended range for glass closures. Results indicated a general trend of increasing vacuum as temperature increased from 82 to 93°C, with variations due to experimental conditions *(Fig. 7)*. For both headspaces, no effect of lid type was found on the vacuum at the temperatures tested. Vacuum increased significantly when comparing values at 82 versus 93°C for 6% headspace with both lid types and for 10% headspace with VRA lug lids. Both lids performed equally well for producing and maintaining adequate vacuum of at least 30 cm Hg, measured at 19 to 20°C, in the closed jars filled with water.

**Effect of hot-pack temperature and headspace on removal torque**

The amount of force needed to remove the caps, as measured with a torque meter, are presented in *Table 1* and *Figure 8* for deionized water and tomato sauce. The removal torque needed to open glass jars with VRA lug lids after pressing the button was significantly lower than that required for the standard lug lids tested. Pressing the button released the vacuum in the jar, resulting in much less force required to open it. Similar results were obtained for both deionized water jars and tomato sauce jars. No significant effect of headspace on torque values was found at the same hot-packed temperature; therefore, the data presented represent the average of the 6 and 10% headspace values. For the VRA lug lids, the removal torque was not affected by the product in the jars (deionized water or tomato sauce) nor by the hot-pack temperature; the values were not significantly different, remaining low on all jars (average of 1.6 N m). For standard lug lids, the average removal torque was significantly higher (2.4 N m); the average torque needed to remove the lids (1.8 N m) decreased after vacuum measurements made by lid piercing. This result seems to indicate that even higher hot-pack temperatures and higher vacuums, which can be obtained by using steam flush cappers, may not increase the removal torque for VRA lug lids and could facilitate jar opening by consumers. According to a study done on VRA lug lids with 79 participants, 100% of the participants found that the lids were easier to open than were standard lids *(9)*. Comparing the mean torque values of VRA lug lids after pressing the button versus standard lug lids, a maximum reduction 50 to 51% was observed for VRA lug lids jars filled with tomato sauce (82 to 88°C with 10% headspace) and a minimum of 20% for jars filled with water at 93°C.

Without pressing the button, the average removal torque values for water and sauce jars sealed with VRA lug lids (2.6

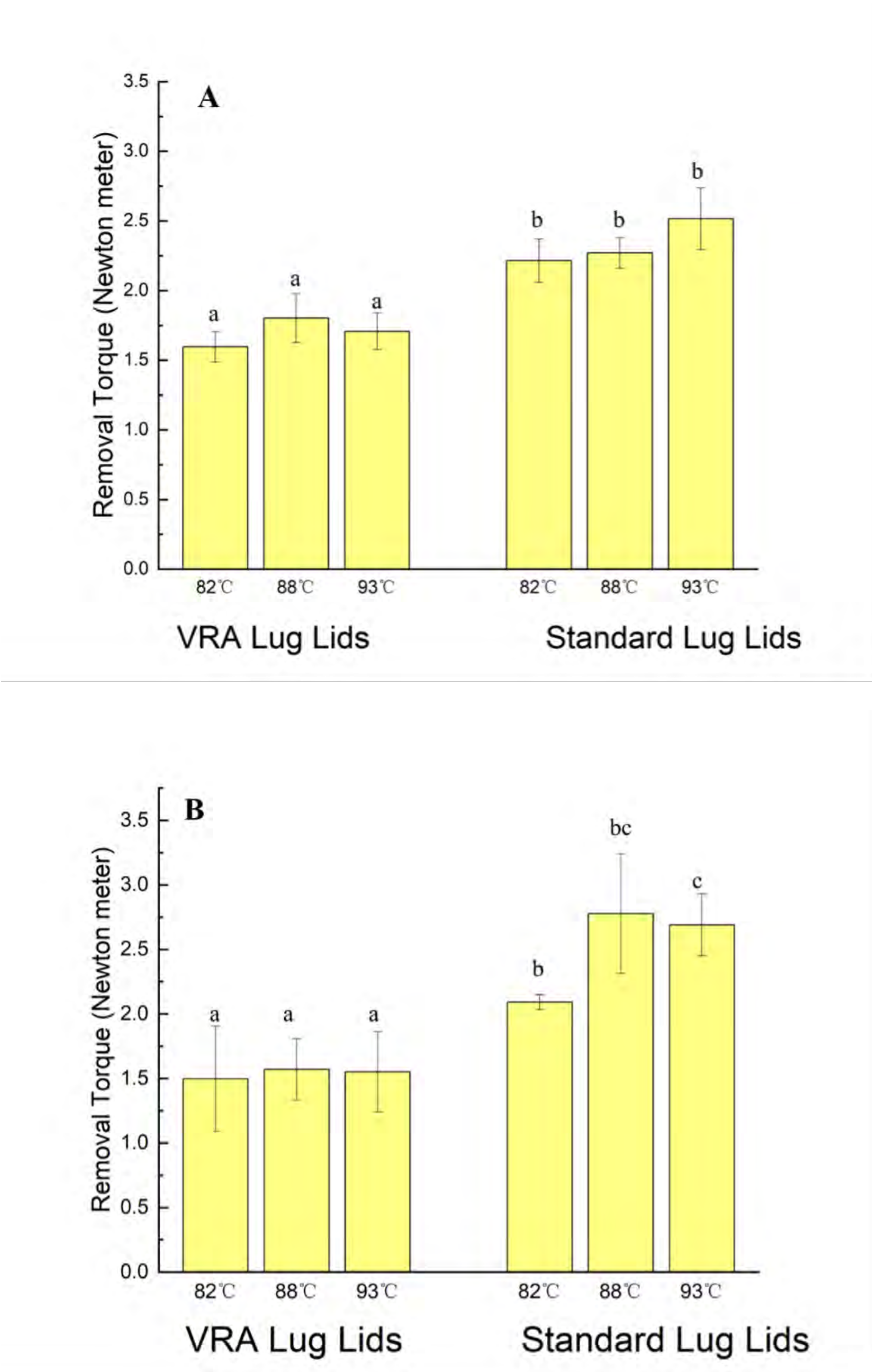


**FIGURE 8. Removal torque for the hot-packed deionized water (A) and tomato sauce (B) glass jars sealed with vacuum release aluminum (VRA) lug lids and standard lug lids (average of the values for 6 and 10% headspaces). Each plotted point represented the mean ± SD of six replicates for headspaces of 6 and 10%. Values of bars with the same letters are not significantly different at $P < 0.05$.**

**TABLE 1. Removal torque for sealed glass jars filled with deionized water or tomato sauce at hot-pack temperatures of 82, 88, and 93°C with headspaces of 6 and 10%[a]**

| Sample | Lid lug type | Temp (°C) | Torque (N m)[b] | | |
|---|---|---|---|---|---|
| | | | After piercing[c] | Without pressing[d] | After pressing[e] |
| Water | VRA | 82 | 1.48 ± 0.25[a] | 2.40 ± 0.17[b] | 1.59 ± 0.11[a] |
| | | 88 | 1.73 ± 0.17[a] | 2.50 ± 0.37[b] | 1.80 ± 0.17[a] |
| | | 93 | 1.80 ± 0.16[a] | 2.68 ± 0.21[b] | 1.71 ± 0.13[a] |
| | Standard | 82 | 1.74 ± 0.12[a] | 2.21 ± 0.15[b] | |
| | | 88 | 1.84 ± 0.21[a] | 2.27 ± 0.11[b] | |
| | | 93 | 1.89 ± 0.15[a] | 2.51 ± 0.22[b] | |
| Tomato sauce | VRA | 82 | | 2.63 ± 0.42[a] | 1.49 ± 0.41[b] |
| | | 88 | | 2.69 ± 0.35[a] | 1.57 ± 0.24[b] |
| | | 93 | | 2.83 ± 0.31[a] | 1.55 ± 0.31[b] |
| | Standard | 82 | | 2.09 ± 0.06[b] | |
| | | 88 | | 2.78 ± 0.46[a] | |
| | | 93 | | 2.69 ± 0.24[a] | |

[a]Each value is the average of that for jars with 6 and 10% headspaces.

[b]Values are mean ± standard deviation; $n = 3$ for deionized water, $n = 5$ for tomato sauce. Within a row, means followed by the same letter are not significantly different at $P < 0.05$.

[c]Removal torque measured after piercing the metal lid of water-filled jars for vacuum measurement.

[d]Removal torque measured for both types of lids.

[e]Removal torque measured after pressing the button of VRA lug lids.

N m) were similar to the average values for jars sealed with conventional lids (2.4 N m) *(Table 1)*, further indicating that hermetic seals were maintained.

## CONCLUSIONS

The use of the new VRA lug lids to seal glass jars for the production of shelf-stable acid foods hot-packed at 82 to 93°C significantly decreased the torque required to open glass jars filled with deionized water and tomato sauce while delivering a hermetic seal comparable to that obtained with standard metal lug closures. The seal integrity and hermeticity of the VRA lids were assessed based on pull-up, vacuum, security values, and removal torque. All parameters had similar results except for removal torque, which decreased by 20 to 51% depending on hot-pack temperature and headspace. The utilization of the VRA lug lid for acid food products packed in glass containers may benefit consumers by facilitating lid removal.

## ACKNOWLEDGMENTS

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