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To: Sophomore Engineering Clinic Staff
From: Jane
Subject: White Paper on Brown Sugar Dehydration

Abstract

A common problem that people have in their homes is not using all of their brown sugar before it hardens. The hardening occurs when the moisture in the brown sugar evaporates. This problem could be significantly eliminated by storing the sugar in a container that minimizes the evaporation possible, thus keeping the moisture in the sugar and preventing it from clumping together. The best possible container would be one that keeps the air in the container with the sugar humidified. The extra water vapor in the air would prevent the moisture in the sugar from leaving the sugar. This would be possible by having a special lid that could hold water but allow water vapor to enter the container through a material that is waterproof but permeable to water vapors.

Introduction

Brown sugar is a common household item that does not always get frequent use. It sits in the kitchen until it is needed for baking. Brown sugar is most commonly used as a sweetener and is chosen over other sugars because of its distinct flavor. However, the infrequent use means that the brown sugar often dries out and becomes hard in between uses. This can cause many problems when trying to use the sugar. If all of the sugar dries out in a solid mass, it can be almost impossible to scrape off any useful quantity of sugar. Other times, the sugar may dry out in pieces and clump together. Although it is easy to gather the clumps of sugar, they are not useful for baking. When brown sugar is measured, it is supposed to be tightly packed and

pressed together to get an accurate measurement. The clumps of sugar make it impossible to pack the sugar and obtain the proper measurement.

Brown sugar is a composition of white table sugar (sucrose) and molasses, a byproduct of sugar cane processing [1]. Sucrose ($C_{12}H_{22}O_{11}$) is formed when D-Glucose ($C_6H_{12}O_6$) and D-Fructose ($C_6H_{12}O_6$) condense [2]. The molasses is the component of brown sugar that provides the sugar's moisture. Molasses is generally about 17-25% water and 77-84% solids by drying [2]. The most predominant sugar in molasses is sucrose (30-40%) with trace amounts of glucose and fructose [2]. Sucrose, glucose, and fructose are all soluble in water so molasses is a homogenous mixture. As the water in the molasses evaporates, the sugar is losing its only source of moisture. This loss of moisture is the cause of the sugar becoming hard and clumping together.

Definition of Problem

Brown sugar that is purchased in the store and used for most common baking purposes is not a raw sugar product with a single chemical formula. It is actually a mixture of white table sugar with a small amount of molasses. The molasses is capable of retaining much more moisture than the white sugar and is responsible for giving brown sugar its moist consistency. When brown sugar gets hard and clumps together, it is because the molasses has lost its moisture. Therefore the problem lies in keeping the moisture in the molasses that is mixed with the white sugar.

There are some common temporary solutions to this problem. Placing a damp paper towel in the container holding the brown sugar provides enough moisture to the air in the container to hydrate the sugar again. Once the towel dries, it must be replaced or the sugar will harden again. If all of the moisture leaves the sugar and it becomes a solid brick of brown sugar,

it can be placed in the microwave next to a container of water and heated for a couple of minutes. The moisture from the water will soften the sugar enough so it can be used, but it will be hardened again for the next time it is needed. Along with only being temporary, these solutions only address the problem after the sugar has already lost its moisture. A more convenient solution would prevent the sugar from ever drying out in the first place.

To find a more permanent solution, this problem could be approached from two angles. First, the problem could be approached by focusing on the sugar itself. The key to keeping the sugar from hardening is keeping the moisture in the molasses. If the sugar could be molecularly altered so that it would always retain its moisture, the sugar could be kept in any kind of container without drying out. Because sugar is an organic molecule, altering the sugar would probably involve genetically altering the sugar cane plant that the sugar comes from. Further research would need to be done to see if this is even possible because most current research with sugarcane focuses on increasing the yield of sugar from one plant [3]. If it is possible, this would still be a risky way to address the problem. Consumers may question a natural product that has been genetically or chemically altered. There is also the possibility that altering the chemical composition of the sugar could change its flavor.

Therefore, if the sugar cannot be changed in a beneficial way, the problem could be addressed by designing a container capable of keeping the sugar moist. This would involve finding a material that would need to be air tight. It would also be most effective if there was as little air as possible trapped in the container with the sugar. Less air trapped in the container would keep the evaporation of moisture from the sugar to a minimum. Another option would be to create a container that adds additional moisture to the air in the container so the sugar can absorb the moisture it needs from the air. Addressing the problem by designing a new container

would be a better idea because it would provide a more efficient and permanent way of preserving the sugar.

Potential Solution

There are two containers that have the potential to solve this problem. The first involves a container where the volume of storage space is adjustable. By adjusting the amount of space the sugar is being stored in, the amount of air in the container will not increase as the sugar is used. This means the moisture will not evaporate into the dry air in the container. This would work as long as the container is made out of materials that are not permeable to air.

The container would be a hollow plastic cylinder with an adjustable base. The interior of the container would be threaded so the base could be raised or lowered as needed by screwing it up or down. The base could have a rubber o-ring around its edge so that it would make an airtight seal with the sides of the container. Once the sugar is placed in the container, the base could be adjusted so that the top of the sugar is as close to the lid as possible (Figure 1). The container would have an airtight lid that would screw on to the top.

This setup would help keep the sugar moist in the same way that a vacuum sealed bag would work. When the sugar dries out, the moisture in the sugar evaporates into the surrounding air. Eventually, the rate of evaporation will equal the rate of condensation of the water vapor in the air. When this occurs, the sugar and the air will be in equilibrium [4]. By eliminating most of the air in the container, the small amount of air left in the container would reach that equilibrium point after only a small portion of the water in the sugar evaporated, leaving most of the moisture in the sugar's molasses. A container with this sort of design would be effective and easy to use as long as the consumer remembered to raise the bottom of the lid after each use. It

would also have the added advantage of keeping the sugar near the top of the container for easy access.

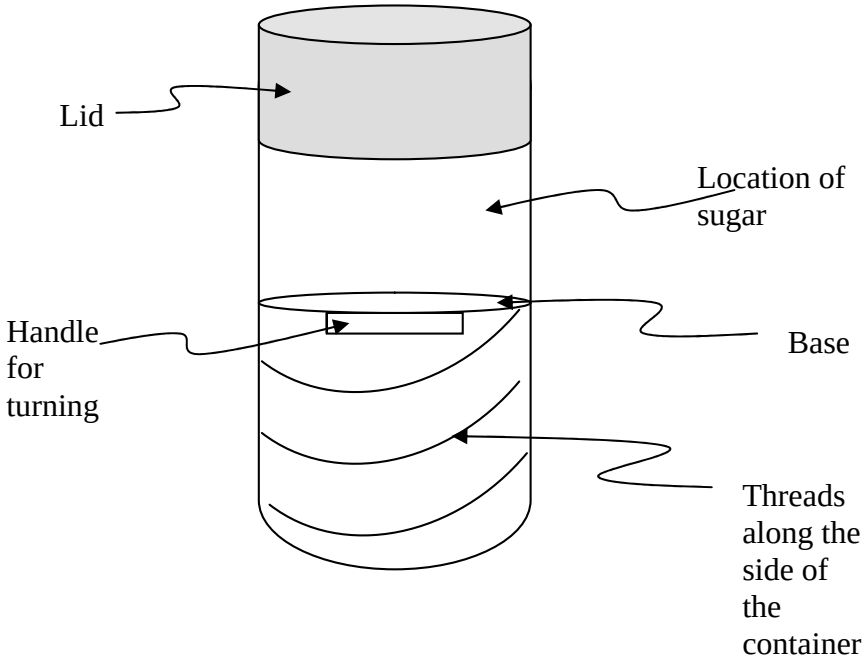

Figure 1. Container for Brown Sugar Storage with Adjustable Base Height
The height of the base can be adjusted by turning the base and moving it up or down. This allows for less air to be stored with the sugar so the moisture in the sugar will not be able to evaporate.

The second design for a container would keep the air in the container humidified so the sugar would not lose its moisture. This container could also be made of plastic, or it could be equally efficient made out of glass. The key feature of the design would be the lid. The lid would have a hollow container incorporated into it that could hold water. There would be an opening in the top of the lid with its own cover where water could be poured into the lid (Figure 2).

The base of the section of the lid holding the water would be made with a waterproof and breathable fabric (Figure 2). This means that the fabric would be able to retain the water in the lid without dripping onto the brown sugar. One possibility for this fabric would be a material used to make some seamless, waterproof, breathable medical supplies. This material consists of a first layer that is a microporous thermoplastic polyester polyurethane or polyether polyurethane and a second layer that is nonporous copolymer [5]. The first layer is permeable to water vapor, and the second layer is waterproof as well as being permeable to water vapor [5]. Using this type of material in the base of the lid would allow some of the water vapor from the water in the lid to pass into the container where the sugar is located. The water vapors passing through the material into the container would keep the air in the container humidified.

Humidifying the air in the container would increase the concentration of water vapor in the container. This addition source of water vapor, would also contribute to the system's equilibrium states. The increased initial concentration of water vapor would decrease the amount of moisture that would need to evaporate from the sugar in order for equilibrium to be reached [4]. This would keep the moisture in the sugar and prevent it from drying or clumping together.

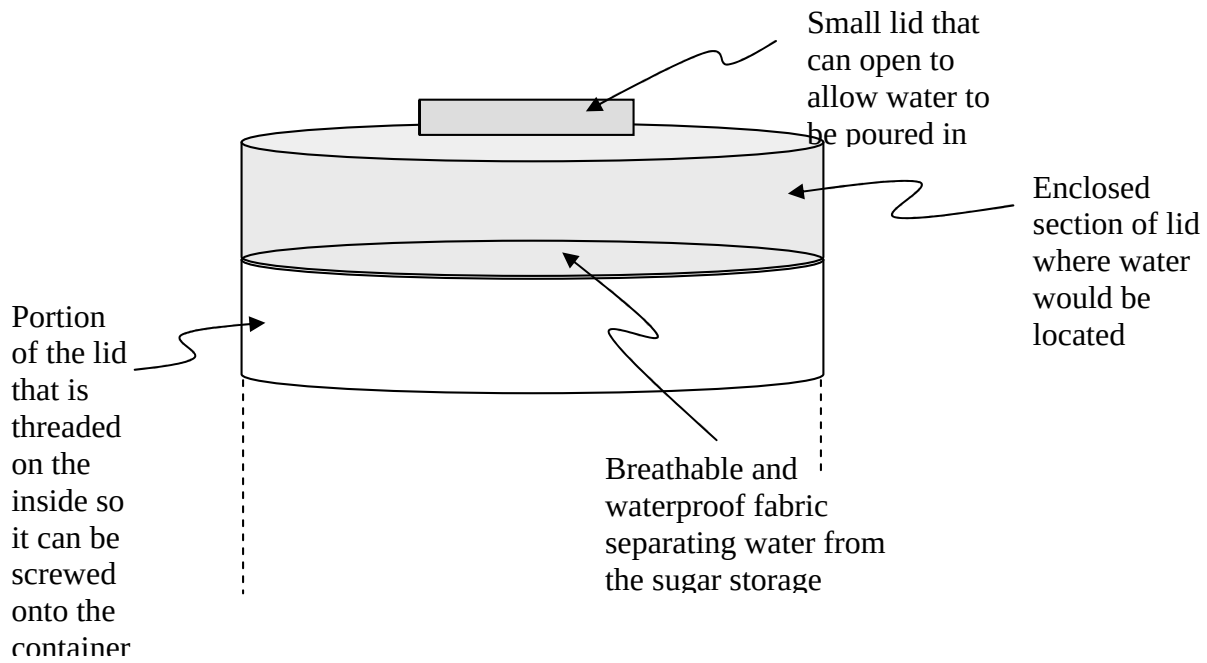

Figure 2. Humidifying Lid that can Hold Water
The lid shown above has a small container that holds water. The container holding the water would be located in the shaded portion of the figure. Water vapor is able to pass into the container through the breathable and waterproof fabric that makes up the bottom of the container. The portion of the diagram that is not shaded is the part that would be threaded so it can be screwed onto the container, indicated by the dashed lines.

Conclusion

Although there are many home remedies for softening brown sugar that has lost its moisture, none of them provide a lasting solution. Of the two containers proposed, both would provide a lasting solution to storing brown sugar in a way that prevents it from drying out. However, for the container with the adjustable bottom used to control the volume of the container, some problems could be encountered with consumers forgetting to move the bottom after using some sugar. If they forget to adjust the height of the base, the container will not be functioning properly and the sugar may still dry out.

Therefore, the container that humidifies the air in the container by allowing water vapors from the lid to pass into the container would be the better option. Before being able to produce this container, further research would need to be done to determine the exact material that would provide the necessary flow rate of water vapor into the container. Also, the exact volume of water needed in the container would need to be calculated after the material was chosen. Producing such a container would allow people to purchase a box of brown sugar and store it in a way that they could be sure it would remain soft and fresh. It would greatly improve the ease with which people would be able to cook with brown sugar because they would no longer need to waste time trying to soften it.

References

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